FOREWORD

The following project was supported by the Biomedical Initiative Steering Committee, United States Special Operations Command. This group coordinates basic and clinical research, as well as research and development, projects designed to enhance the abilities of Special Operations medics, corpsmen and pararescuemen to care for casualties in the Special Operations Environment. The project presented was performed by Combat Trauma Research, Department of Resuscitative Medicine at the Walter Reed Army Institute of Research, Silver Spring, Maryland.

Naval Special Warfare Group One Medical and Group Two Medical made this research possible by coordinating Special Operations medical care personnel schedules to allow for evaluations. In addition, through COMNAVSPECWARGRU One Medical's Advanced Battlefield Trauma Course, we were able to obtain additional assessments. The efforts of Group One and Group Two Medical, as well as those of the Special Operations corpsmen and pararescuemen that participated in our evaluations, are greatly appreciated.

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13. ABSTRACT *(Maximum 200 words)*

BACKGROUND: In the tactical and CASEVAC phases of Special Operations medical care, airway and breathing are assessed, followed by evaluation of circulation. Although controversial, fluid resuscitation of casualties with potential uncontrolled hemorrhage until return of mentation (showing adequacy of cerebral perfusion) or the return of a palpable radial pulse has been recommended Excess amounts of fluids are discouraged in order to avoid causing further hemorrhage. Controlled administration of fluids, as well as medications such as antibiotics, may be easier to attain with infusion pumps. METHODS: Fourteen possible infusion pumps were identified. Laboratory Evaluation: Weight and dimensions were measured. Infusion rates of normal (0.9%) saline (NS), hypertonic (7.5%) saline (HS) and hetastarch (Hespan) were evaluated. Accuracy relative to the company-claimed rates (for those systems able to infuse at specific rates) was evaluated. Special Operations Corpsmen and Pararescuemen Evaluations: the 14 devices were assessed followed by completion of a questionnaire regarding advantages, disadvantages, desired changes, particular pumps that would be carried in the field and their previous experience with infusion of fluids in the field. RESULTS AND CONCLUSIONS: Most devices were relatively accurate with NS and HS, but not as good with hetastarch. Smaller infusion pumps that would be used for medication (i.e. antibiotic) administration were largely felt unnecessary. The soft covered elastomeric balloon has potential as a carrier and infuser of hypertonic fluids should that fluid be used in the future. The M100 electronic pump, which allows complete hands-free use even when a fluid bag is below the patient, is desirable for insertion/extraction platforms. Many pumps are not appropriate for the Special Operation environment. The best option for the field at present are collapsible, rugged, relatively inexpensive and proven pressure-bag based units. An attractive alternative, is the Y-type Blood Set, originally intended for administration of blood, which utilizes IV tubing with an in-line squeeze bulb capable of delivering rates similar to squeeze bag systems. This option is proven and would replace existing primary IV tubing sets.

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Infusions Pumps: Potential Application for Special Operations Environment

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Objective:

The objective of this project was to identify infusion pump systems with potential application for the Special Operations environment.

Background:

In the tactical and CASEVAC phases of Special Operations medical care airway and breathing are primary concerns followed by circulation issues. Intravenous (IV) access is obtained at the appropriate time. Fluid is administered to those without uncontrolled hemorrhage. Treatment for those with uncontrolled hemorrhage is controversial. Although some recommend avoidance of fluids altogether, others recommend titrating fluid administration until consciousness returns or a radial pulse is felt with hopes of maintaining some perfusion to organ systems without leading to further hemorrhage. Care must be taken to avoid giving the combat casualty too much volume. Infusion pump systems may allow controlled administration of fluids for resuscitation and medications. In addition they may allow hands-off administration of fluid. For these reasons the Biomedical Initiative Steering Committee tasked Combat Trauma Research (WRAIR, Department of Resuscitative Medicine) with evaluating infusion pumps.

Our goal was to (1) perform a literature review, (2) identify existing infusion pump systems with potential far forward application, (3) obtain those identified units and evaluate them within our lab and (4) have 18-Deltas evaluate the devices for potential in the Special Operations environment.

Methods and Results:

Literature

Review of the literature revealed no studies looking at infusion pump usage in the combat, far forward, prehospital environment. Therefore, pumps were identified by commercial means.

Identifying Equipment

Ideal infusion pumps for the field would be rugged, lightweight, compact, quiet, simple, have minimal moving parts and not require a limited power supply. These became rough criteria when identifying available systems.

These pumps may function to provide volume resuscitation and/or controlled administration of a specific drug. Power may come from an inflation bladder, metal leaf or coil spring, rubber band, elastic balloon, squeeze pump or battery source.

Pumps were identified by catalogs, medical meetings, personal communications, as well as knowledge of clinically used pumps. Fourteen different systems were discovered in all. Some of these systems had a number of different volume and rate options. These units are described individually under laboratory evaluations.

WRAIR Laboratory Evaluations

Laboratory evaluations took place at the Walter Reed Army Institute of Research, Department of Resuscitative Medicine, Combat Trauma Research. Factors assessed included weight, dimensions, accuracy of reported infusions rates (where applicable), as well as subjective assessment regarding simplicity of operation and durability. Table 1 provides a comparison of measured weights and dimensions, price, as well as probable type of usage.

Accuracy (for pumps reporting ability to pump at specific rates) and infusion rates were recorded by measuring volumes infused over time. This was accomplished using LabView software and a personal computer connected to a graduated cylinder placed upon a scientific scale. Normal saline (0.9%), hypertonic saline (7.5%) and hetastarch were tested with each infusion pump. The pumps (those able to pump at a specific rates) delivered approximately the company's reported rate when infusing normal saline and hypertonic saline. Hetastarch resulted in slower infusion rates. See Graphs 1 through 18. Further accuracy testing with a system such as that developed in our lab would be recommended if a particular rate specific pump was chosen.

The Medi~SIS Syringe Infusion System (I-Flow Corporation, Lake Forest, CA) is pictured in figures 1 and 2. It consists of plastic cylinders which are threaded into one another. The inner cylinder contains a spring which supplies the power behind the infusion pump. A 20 ml or 60 ml syringe is loaded into the cylinders and pressure applied to the plunger of the syringe. The fluid within the syringe is then forced out

through tubing which would be connected to an intravenous (IV) catheter. Size and weight make field use unlikely. This system would most likely be used for administration of IV medications such as an antibiotic. However, this can also be easily performed manually in the field by incremental injections followed by patient observation. Because it was felt that this pump had no potential for the field, accuracy was not evaluated.

The SpringFusor (Mila International, Inc., Florence, KY), approved for veterinary use, utilizes an internal spring which places pressure against the plunger of a syringe inserted into the cylinder of the pump. Several different sized SpringFusors are available, one of which is seen in Figure 3. The tubing connected to the syringe (see Figure 4) controls rate of infusion. Although smaller than the MediSIS, this pump is still too bulky. Because we felt this was not a viable option for the field, we chose not to report on its accuracy. Manual incremental injections would probably accomplish the same objective without the need to carry additional items.

The BandIt (I-Flow Corporation, Lake Forest, CA) obtains its power from a rubber band stretched over the plunger of a syringe (see Figure 5). Rate is controlled by tubing of a specific diameter and length. Different size BandIts are available for different size syringes. This type of system is very small, lightweight, compact and simple. Of those units used for administration of medications such as antibiotics, this is probably the best option for the far forward setting. Graph 1 shows a reasonable infusion rate for antibiotic administration.

Baxter Intermates (Baxter Healthcare Corporation, Deerfield, IL) contain an inner elastic balloon (called an elastomeric reservoir) and an outer plastic protector which looks like a baby bottle (Figure 6). A number of different volume and rate options are available (Figure 7). Small volume (SV) holds 100 ml, while large volume (LV) holds 250 ml and extra large volume (XLV) holds 500 ml. Rates can vary from as low as 50 ml/hr to as high as 250 ml/hr. These units are intended for single use only. The elastic nature of the balloon provides sustained internal pressure to power the pump, while a particulate matter filter and flow restrictor control rate of infusion. Although the Intermate system can be used for low rate medication administration, it is more likely that it would be used for higher volume fluid resuscitation. The plastic outer portion appears to be quite fragile and concerns center about its bulky nature and potential to break within a rucksack. Graphs 2 and 3 show infusion of normal saline, Graph 4 shows infusion of hypertonic saline (7.5% saline) and Graphs 5 and 6 shows infusion rate accuracy with hetastarch (Hespan). Hetastarch was delivered at slower rates than the stated infusion rate. It should be noted that the company does not recommend use with colloids because the

Intermates do not deliver that fluid at the intended rates for crystalloids such as lactated ringers (LR) or normal saline.

The DIB (Drug Infusion Balloon, Novacon Corporation, Lake Elmo, MN) contains an inner elastic balloon which serves as a fluid reservoir similar to the Baxter Intermates. DIBs have either a "baby bottle" covering or an outer soft, collapsible plastic protector (see Figure 8). A variety of volumes and infusion rates are available. These devices function similarly to the Baxter Intermates. The DIBs can provide slow infusion for medications, but would most likely be useful for volume infusions in the field. Due to the collapsible nature of the soft protector, this system would be more appropriate for the Special Operations setting. In addition, this soft outer would not crack within a rucksack. It is foreseeable that these could be preloaded with a set amount of hypertonic saline which could then be administered in a rapid, yet controlled manner. Infusion rate accuracy of normal saline is seen in Graphs 7 and 8, in addition to hypertonic saline infusion seen in Graph 9.

The Israeli Spring, shown in figure 9, is employed by the Israeli military for higher volume infusions. It consists of foldable metal springs, covered in green nylon, which apply pressure upon a 250 ml, 500 ml or 1000 ml fluid bag placed within a nylon sleeve inside of the spring device (see figure 10). Rate of infusion is roughly controlled by a strap that pulls the spring leafs together. Increasing tension must be applied to maintain relatively constant infusion rates as the volume in the bag decreases. Obviously, this pump would be used for rapid volume delivery. While quite durable, the Israeli Spring is somewhat bulky, as well as heavy. Infusion rates are comparable to those seen with other external pressure devices. An example of infusion rate obtained with normal saline and hetastarch is seen in Graphs 10 and 11, respectively.

Liberty 100 (I-flow Corporation, Lake Forest, CA) applies pressure to a 100 ml fluid bag placed into a contained chamber. A crank, stored on the back of the device, is inserted and wound, which results in an internal squeezing of the fluid bag. This pump system is heavy, bulky and fragile (see figure 11). Like some of the low volume infusion pumps, this pump was not tested for accuracy due to its inappropriateness for the far forward environment.

IV Push (MTM Health Products, Ltd., Burlington, Ontario, Canada), seen in figures 12 and 13, consists of a plastic box and a metal spring. A 1000 ml bag is placed into the box and the spring stretched over the IV fluid which allows high, rapid rates of volume infusion. This device is heavy, bulky and appears to have the potential to break. An example of the infusion rate obtained with normal saline is seen in Graph 12. A tapering

of flow is seen after approximately 11 minutes. A similar finding was seen with hypertonic saline (plateau at 750 cc at 11 minutes) and hetastarch (plateau at 375 cc at 15 minutes), although this is not shown.

The Microject Infusion Pump (Microject Corporation, Salt Lake City, UT) is largely employed as a home health care item. It allows a variety of infusion rates, from very slow to relatively fast. The plastic pump contains internal batteries and works with specific IV tubing (see figure 14). Infusion rates are adjusted by a series of dials on the backside of the pump. Adjustment is not self-explanatory, which requires some additional reading. Fragility and internal batteries limit this pumps' usefulness for the field, which is why we do not report on accuracy. Although a newer model now utilizes standard batteries, that model was not available for testing by our team.

The M100 Resuscitation Pump (Infusion Dynamics, Plymouth Meeting, PA), shown in figure 15, was designed for large volume infusion during trauma resuscitation. This electronic pump infuses at rates from 200 ml to 6000 ml per hour. When the pump is turned off, flow occurs at a rate determined by standard IV tubing roller stops. Figure 16 shows the M100 and its specific cartridge (inserted on the side seen with rocker arms) which connects to standard IV tubing and extensions. A single credit card-sized battery allows usage for 5, 11 or 24 hours of use when running at rates of 6, 2 and 0.2 liters per minute (LPM), respectively. A newer model, which uses 6 AAA batteries, will reportedly run 12-15 hours at maximum infusion (6 LPM) and greater than 48 hours when running at 0.2 LPM. The pump does not require an elevated IV fluid bag as it automatically eliminates air and continues to infuse. It is the only truly "hands-free" system. Although dependent upon electric power, it does appear relatively rugged. Its light weight and compact size make it attractive, although it is expensive. Graph 13 demonstrates rapid infusion of normal saline, whereas Graph 14 shows the rapid infusion of hetastarch.

Pressure Infuser (David Clark Company, Inc., Worcester, MA) provides pressure to a half-liter or liter bag of IV fluids allowing for rapid infusion. The rugged nylon encompasses a bladder, inflated by a squeeze bulb, and sleeve into which the fluid bag is inserted (figure 17). The pump collapses for storage. This system appears durable, but is not cheap. This pump can rapidly infuse all three solutions. Graphs 15 and 16 show its ability with normal saline and hetastarch fluids.

Infusable (Vital Signs, Inc., Totowa, NJ) pressure bag system, seen in figure 18, is commonly used in the operating room, intensive care unit and emergency medical system. Both half-liter and liter sizes are available, but both half-liter and liter IV bags

can be placed into the liter sized Infusable. This pump works in a manner similar to that of the Pressure Infuser, although it is made of a slightly thinner nylon material. The Infusable can be compressed compactly and is rather light. Because it also operates by a pressure bladder, there is the possibility of puncture, although this device is rather rugged. Another advantage of this system is its relative cheap price tag. The Infusable's rates of infusion are similar to the Pressure Infuser. Normal and hypertonic saline tests are shown in Graphs 17 and 18.

The Select-3 (Biomedix, Inc., Spencer, IN) system is IV tubing with a drip chamber that allows the selection of three different orifices which alter infusion rates. One's choice is made by twisting the blue flange above the chamber, seen in figure 19. This pump allows controlled administration of fluids, however the choice of rates is limited.

Figure 20 shows the Y-Type Blood Set (Abbott Laboratories, North Chicago, IL), originally intended for administration of blood products and often used in the operating room. The system consists of IV tubing with an in-line blood filter, as well as squeeze bulb, with two one-way valves. The in-line squeeze bulb allows for very rapid administration of fluids without the need for an external compression device. The Y-Type Blood Set would replace standard primary IV tubing and would thus not be an additional item for the 18-Delta to carry. Additional advantages would be its lightweight, compact nature and relatively inexpensive price. Clinical use shows comparable infusion rates compared to pressure bag systems.

Special Operator Evaluations

A total of 26 Special Operations corpsmen and pararescuemen evaluated the above described infusion pumps. Two questionnaire formats were completed. Fifteen corpsmen from Naval Special Warfare Group One and Naval Special Warfare Group Two completed Questionnaire One (see figure 21). Questionnaire Two (see figure 22) was distributed to Air Force pararescuemen, as well as Navy SEAL and Reconnaissance corpsmen (11 additional respondents), attending Group One Medical's Advanced Battlefield Trauma course. The compiled responses are seen in figures 23 and 24.

Discussion:

Seventeen of the twenty six respondents indicated that they do carry an infusion device of some type. Most of these Special Operators are using pressure bag systems like the

Infusable, although a few state that they will use a blood pressure cuff. It is interesting to note that use of the BP cuff for rapid infusion of fluids would take away the ability to use it for monitoring purposes. Of the fifteen people responding to Questionnaire One, nine reported that they felt the need for an infusion pump in the field, mostly because it allowed more hands free fluid administration while performing other duties. The corpsmen or pararescuemen who actually had used devices in the past were more inclined to say they felt there was a need for infusion pumps.

Smaller volume infusion systems, like the Medi-SIS, SpringFusor, and BandIt, were largely felt unnecessary. This related to the Special Operators' belief that those things administered in small volumes could easily be administered by manual, slow intravenous push.

Larger volume pumps were variably rated. The large, fragile and cumbersome IV Push and Liberty devices have no place in the Special Operations Environment. The Intermate and DIB elastomeric pumps were also regarded as largely unnecessary. These devices did not seem to offer any additional advantage considering their disadvantages, such as bulk and fragility. Although an elastomeric infusion pump has reportedly been evaluated at some point in the past by corpsmen supporting Marine Reconnaissance (personal communication with HMC Jack Graham), no report could be located. Apparently, the evaluated systems were considered durable. The collapsible DIB could be considered as a potential container/infuser for hypertonic saline should that fluid be approved for field use.

Of the electric-powered devices, the MicroJect was not favorably rated due to concerns over durability and internal batteries. If the external battery version had been available, ratings probably would have been better. The M100 pump was felt to be excellent for insertion/extraction platforms and to even have potential for field use due to apparent ruggedness and ability to pump fluids no matter the position of the IV bag. Its principal advantage is completely "hands-free" use no matter where the fluid bag is or how much air is in the bag, due to its ability to automatically eliminate air and continue to operate. Its major drawback is price at this moment.

The rugged Israeli spring had ratings spread across the spectrum. Operation without a puncturable bladder offers an advantage. The variability in opinions probably reflects a durable, but heavy and cumbersome piece of equipment.

Pressure bag systems are the most widely carried infusion device. When responding to Questionnaire One regarding which infusion pump they would carry, 14 responders chose

one of these two systems. The pressure bag devices were the most preferred pumps. In Questionnaire Two, the green Pressure Infuser was not as highly ranked as the Infusable, probably due to its slightly more bulky nature as well as its price. These devices allow "hands-free" administration, although one must be careful to avoid infusion of air by either close monitoring or prior elimination of any air within the fluid bag. The white Infusable was one of two devices consistently rated on the high end as either a device that would be carried on all missions or some missions. This piece of equipment is lightweight, compact, simple, inexpensive and works well whether in the operating room or the field.

The other infusion system that was consistently rated on the high end was the Y-type Blood Set. This squeeze bulb IV tubing pumps all types of fluids as rapidly as the pressure systems (clinical experience) and may replace existing tubing (it is slightly more bulky than standard primary IV tubing). Although the bulb must be intermittently squeezed, it does allow some "hands-free" use. The other IV tubing set was the Selec-3. Although different drop rates can be adjusted, this tubing adds very little to existing IV tubing when considering the Special Operations environment.

Conclusions:

Small volume infusion pumps add little to the 18-Delta's ability to care for casualties.

Most large volume infusion pumps are too bulky to be man-packed. The M100 system's ability to pump regardless of bag position is attractive, as this is the only true fully "hands-free" device. This pump holds promise, but a reduction in price is necessary before easy access to this pump exists. The Infusable pressure bag device is probably the best choice for Special Operators at the moment. It is the most widely available, inexpensive and proven piece of equipment. An attractive alternative to the Infusable is the Y-type Blood Set. Because it can replace existing IV tubing and provides weight and volume savings, compared to other pumps, the Y-type Blood Set is enticing.

TABLE 1: Comparison of Weight, Dimension, Price and Type of Use

TRANSFUSION PUMPS	WEIGHT (grams)	DIMENSIONS H x W x L (inches)	APPROXIMATE PRICE ($USD)	TYPE OF USE
Medi-Sis 20	230	1.75 x 1.75 x 7.75	$35 administration set $1.50	Medication Administration
Spring-Fusor 10cc	95	1.5 x 1.5 x 6.25	10cc model $30 30cc model $48 administration set $6	Med. Admin.
Band-It 10cc	30	2 x 1.75 x 1.75	$5.60 administration set $3.60	Med. Admin.
Band-It 20cc	31	2 x 1.75 x 1.75	$5.60 administration set $3.60	Med. Admin
Baxter SV 200	51	2.25 x 2.25 x 4.5	$21	Fluid/Meds
Baxter IM XLV250	80	3 x 3 x 9	$18	Fluid/Meds
Baxter IM LV 100	61	2.5 x 2.5 x 6.25	$29	Fluid/Meds
DIB 2001	55	0.75 x 2.5 x 5.5	$30	Fluid/Meds
Israeli Spring	522	2 x 3.75 x 7.5	Not available	Fluid Administration
Liberty 100	437	2.25 x 2 x 7.5	$150	Fluid Administration
IV Push	761	3 x 6.25 x 14.25	$90	Fluid Administration
Microject	168	2 x 2 x 5	$250 administration set $14	Fluid Administration
M100 w/ battery	269	2.25 x 2.75 x 4.75	$1595 cartridge $29.50	Fluid Administration
M100 battery	31	0.375 x 2.125 x 3.25	$17	
Pressure Infuser	201	2.25 x 3.25 x 6.5	$80	Fluid Administration
Infusable	97	2.25 x 2.25 x 5.5	$18	Fluid Administration
Selec-3 IV	48	1.75 x 2 x 6	$3.50	Fluid Administration
Y-type Blood Set	95	1 x 3.75 x 10.5	$18	Fluid Administration

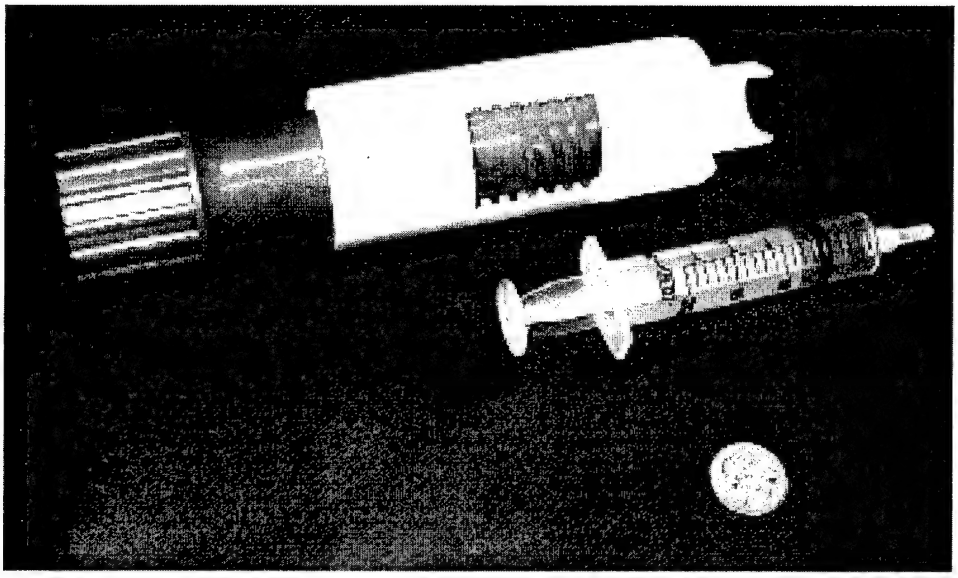


Figure 1: MediSIS syringe infusion system. The photo shows two plastic cylinders threaded into one another.

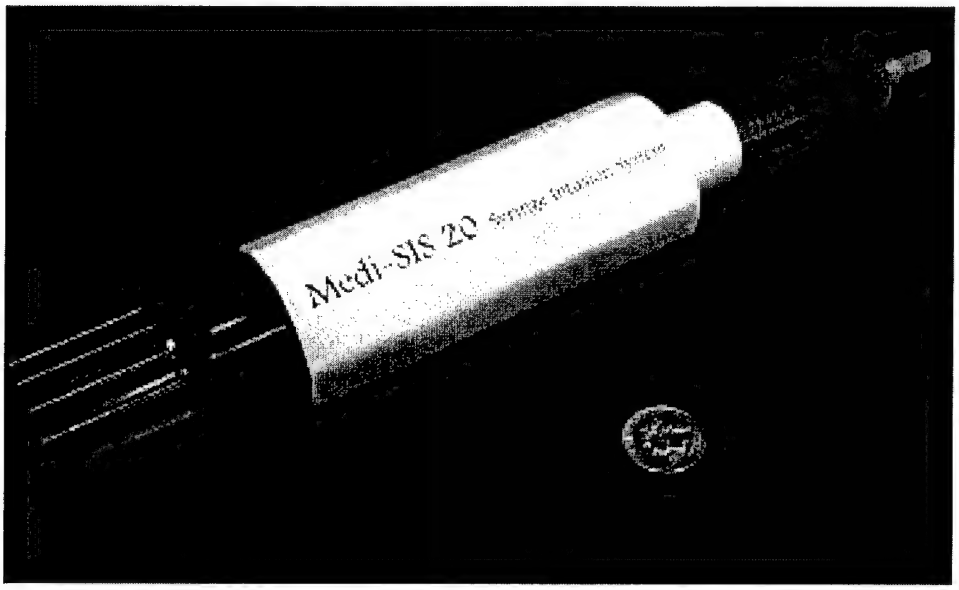


Figure 2: MediSIS syringe infusion system with loaded 20 ml syringe. Power for the pump is provided by an internal spring applying pressure to the plunger of the syringe.

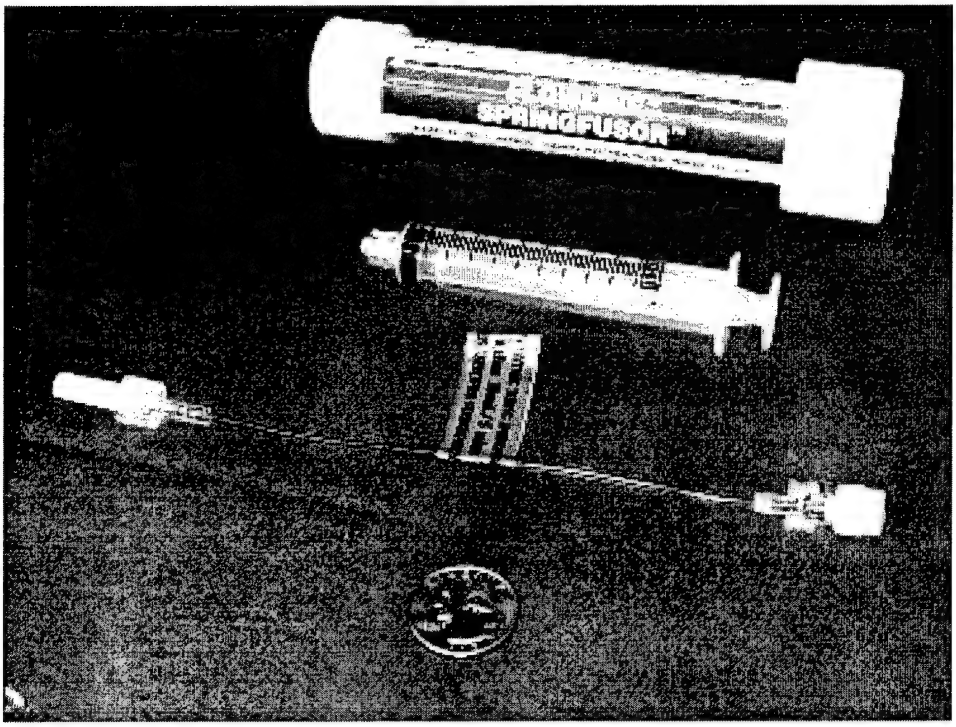


Figure 3: SpringFusor. Ten ml syringe and infusion rate specific tubing are shown.

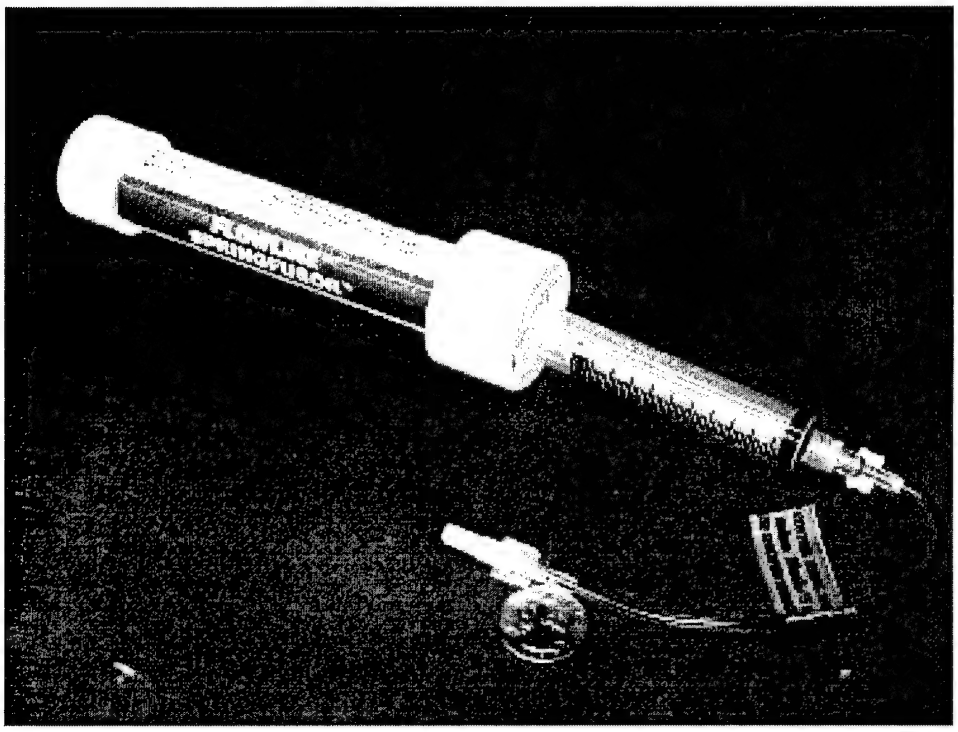


Figure 4: SpringFusor with 10 ml syringe and infusion rate-specific tubing connected.

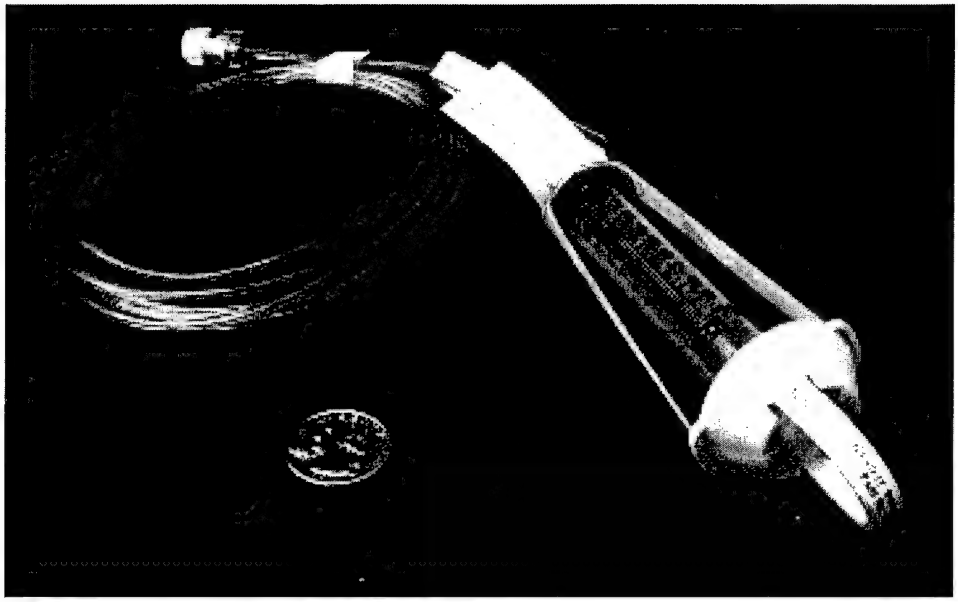


Figure 5: BandIt. This pump is powered by a rubber band stretched over the plunger of a standard syringe. Rate is controlled by tubing of specific diameter and length.

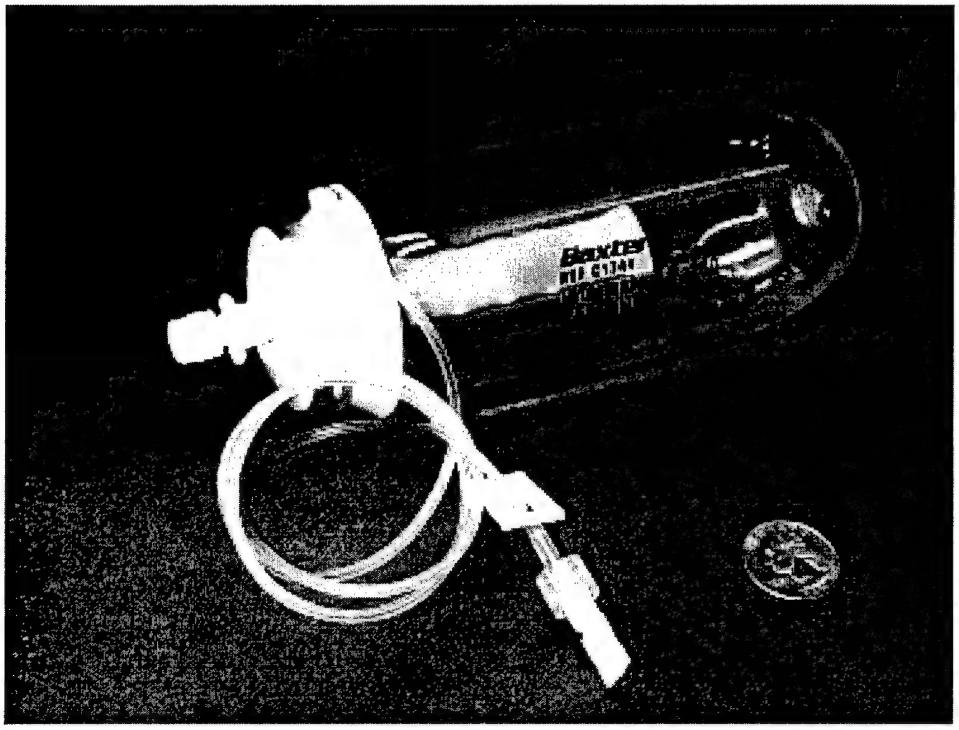


Figure 6: The Baxter Intermate LV 250. An inner elastomeric reservoir provides internal pressure. Large volume (LV) models hold 250 ml of fluid. LV 250 pumps at 250 cc/hr.

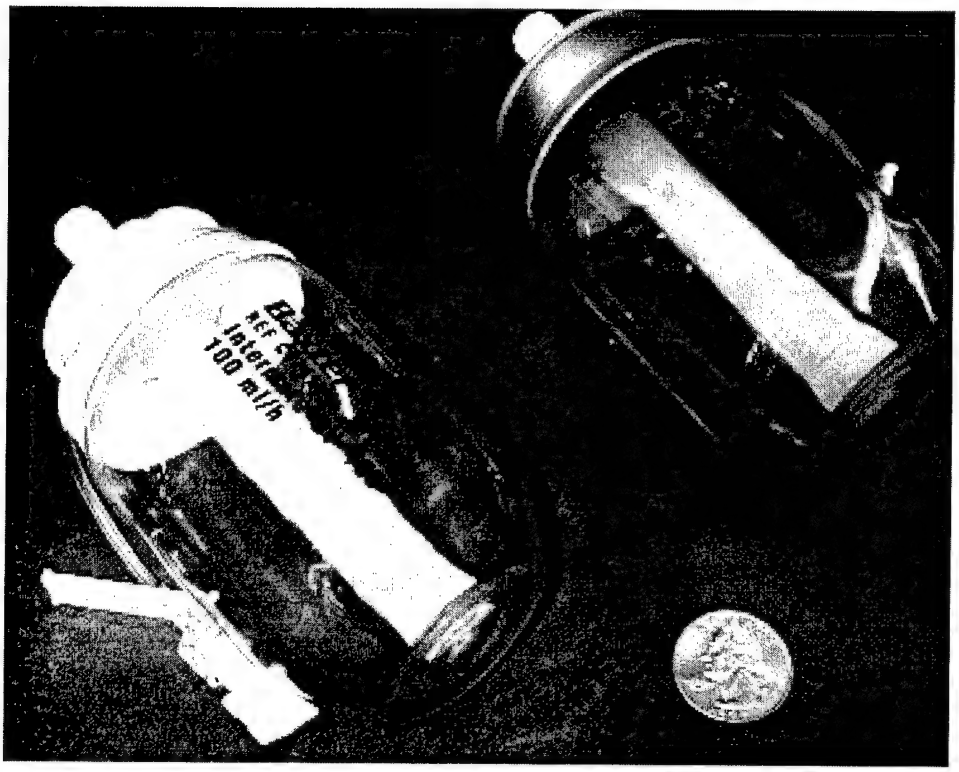


Figure 7: Baxter Intermate SVs. Small volume models hold 100 ml of fluid. The SV100 (pictured on left) infuses at 100 ml/hr, while the SV 200 (on right) infuses at 200 ml/hr.

Figure 8: Drug Infusion Balloon (DIB) 2001 contains a 200 ml reservoir which will be infused over a 1 hour period.

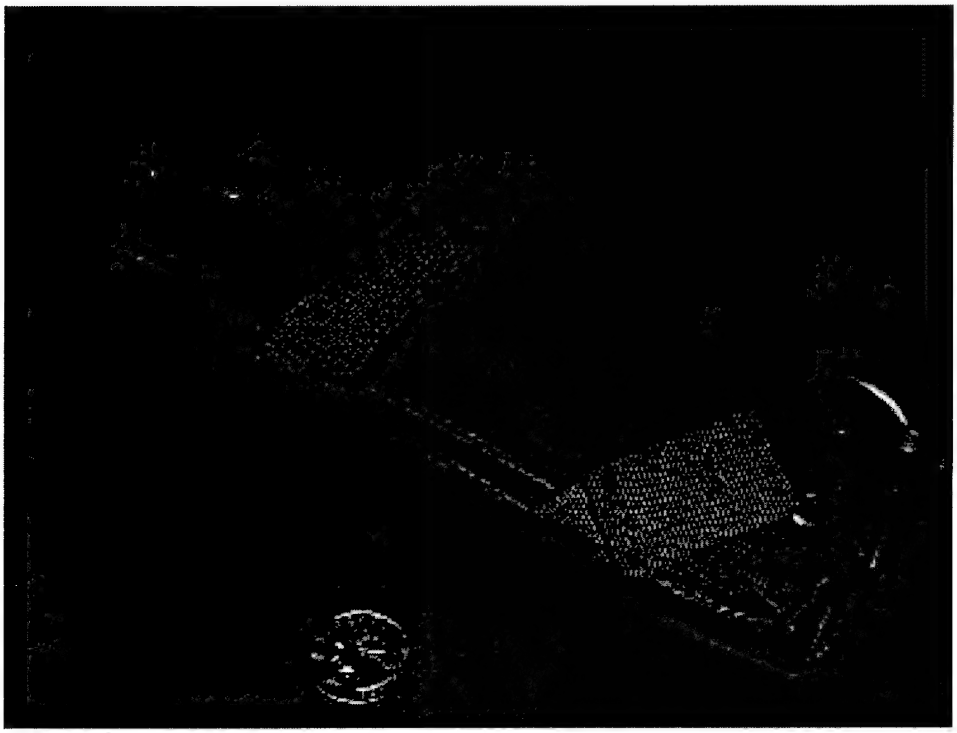


Figure 9: Israeli Spring as it would be carried in its collapsed form.

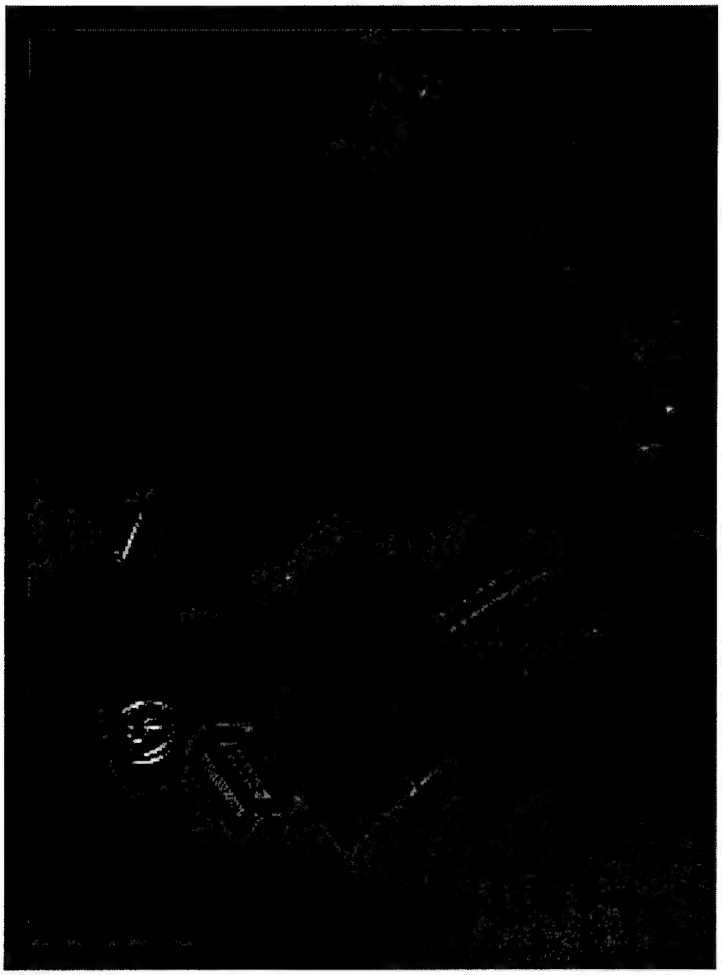


Figure 10: Israeli Spring in its uncollapsed form ready for insertion of a fluid bag into its inner sleeve. The strap applies pressure to each leaf thus roughly controlling rate of infusion.

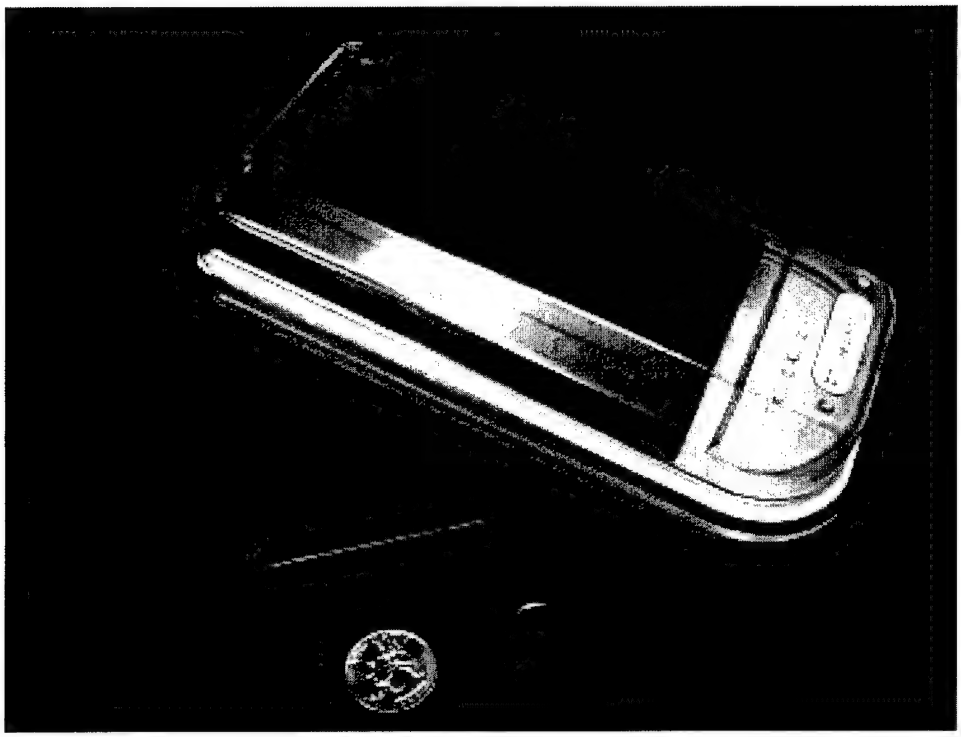


Figure 11: Liberty 100.

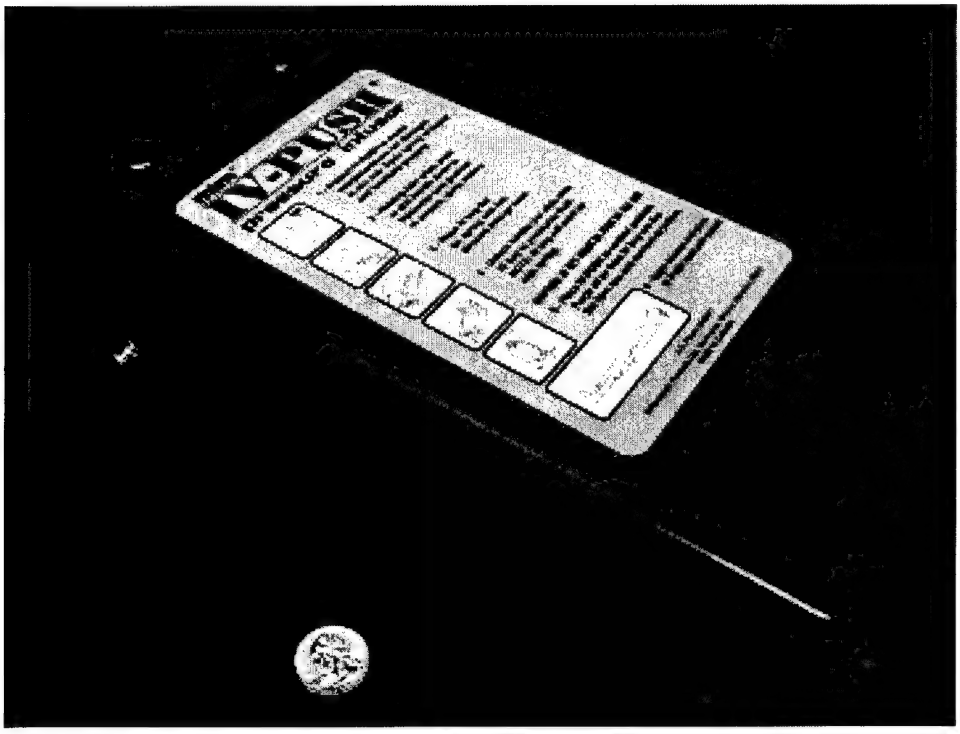


Figure 12: The IV Push with instructions shown on the back.

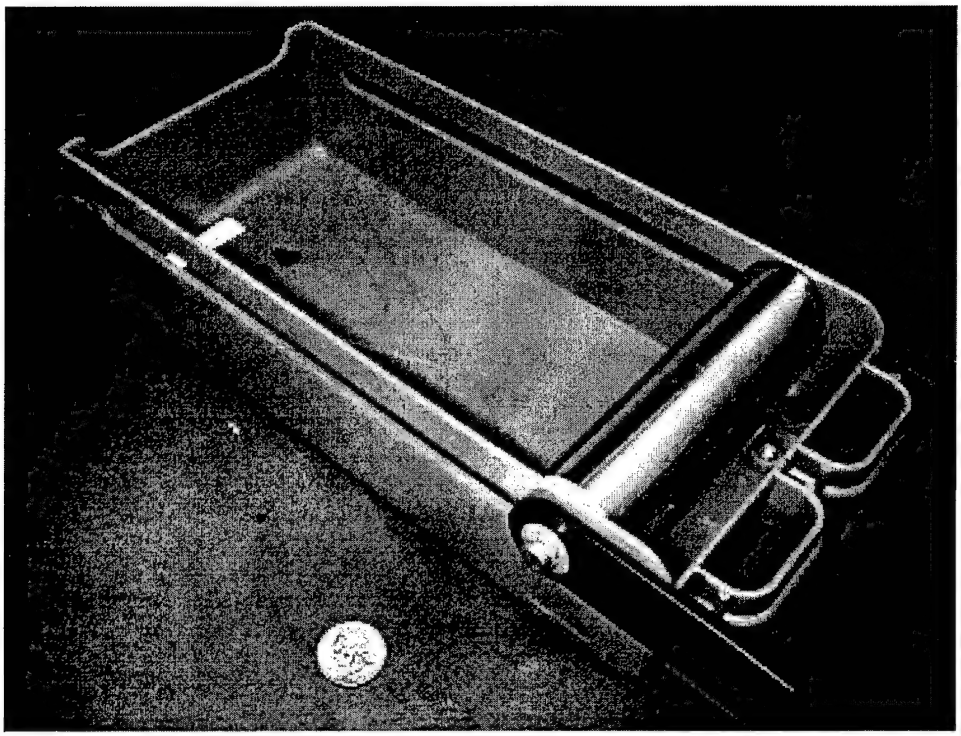


Figure 13: IV Push with plastic box and metal spring.

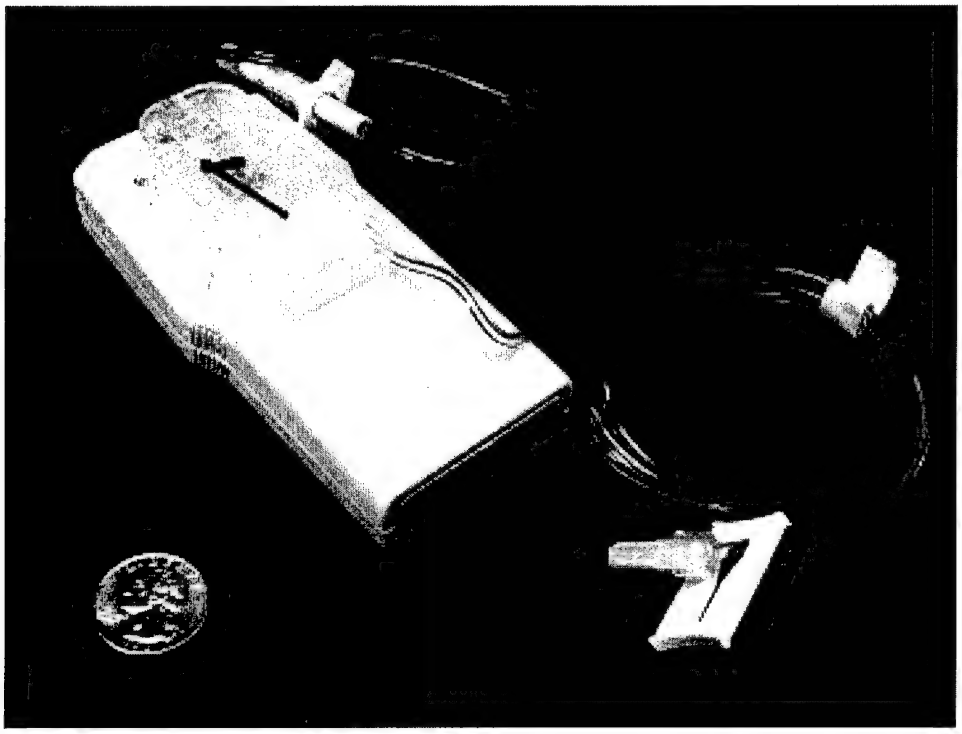


Figure 14: Microject infusion pump shown with its specific cartridge and tubing.

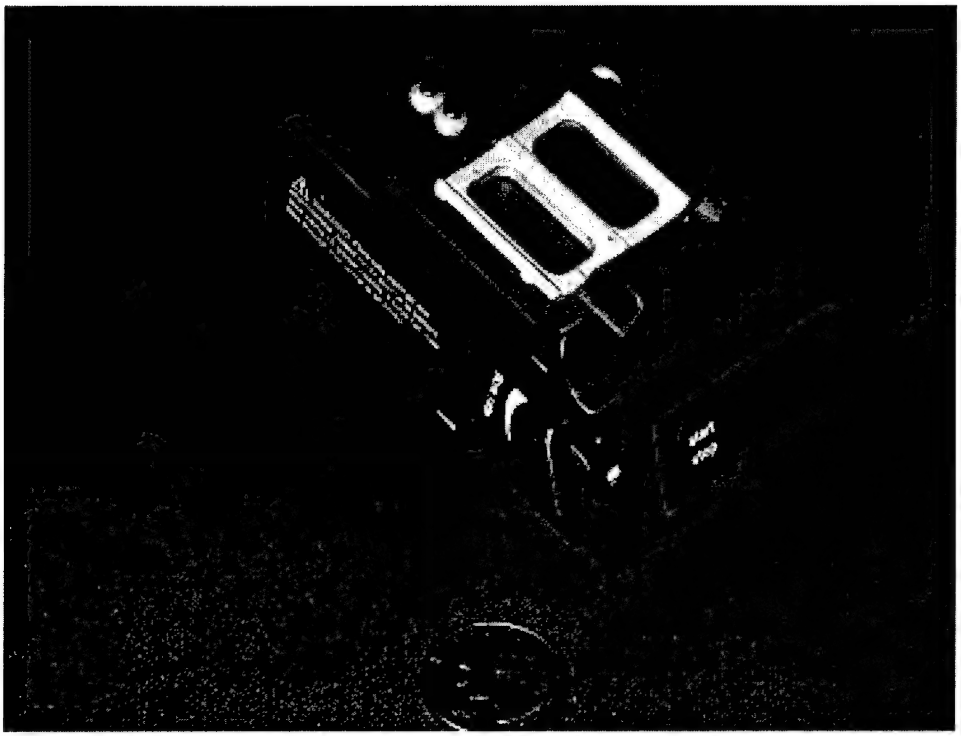


Figure 15: The M100 infusion pump. A credit card-sized battery is inserted on the underside of the device.

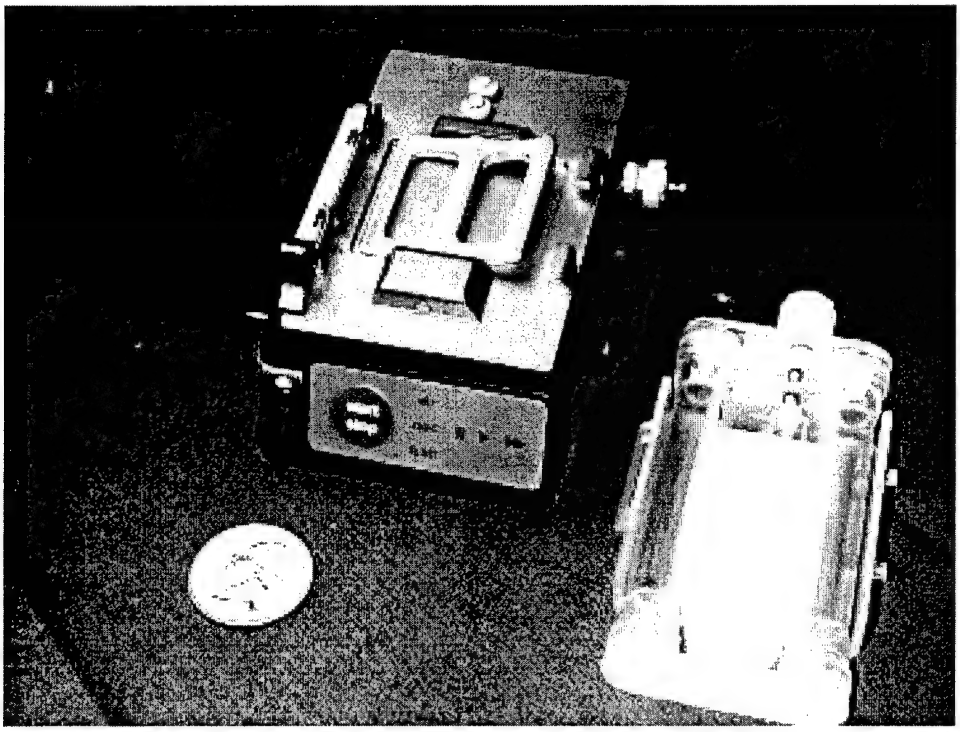


Figure 16: The M100 with its cartridge which connects to standard IV tubing.

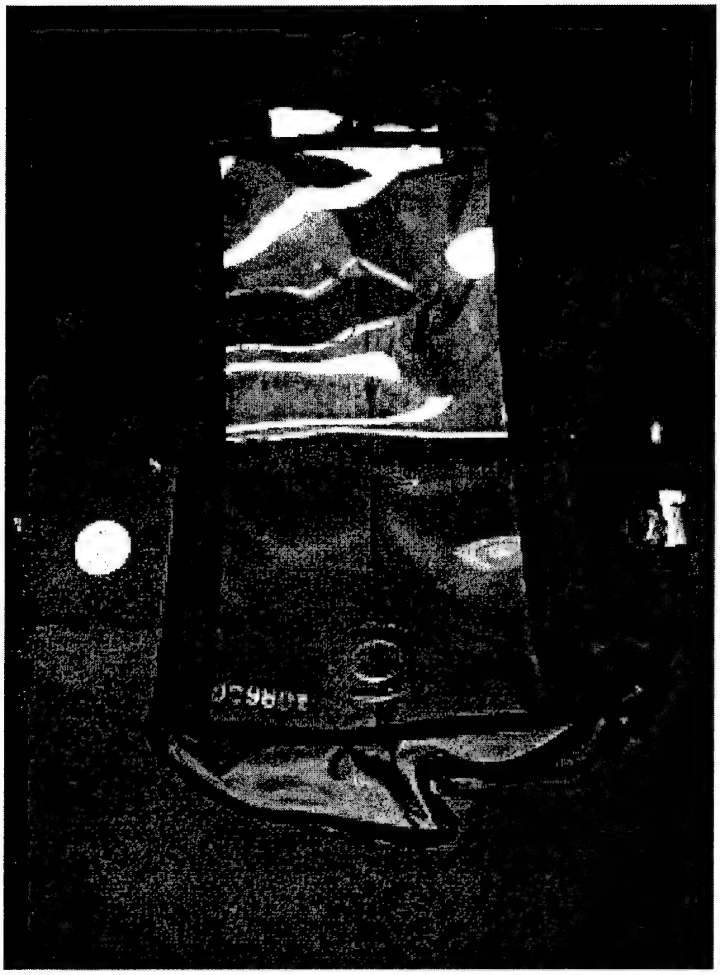


Figure 17: Pressure Infuser inflatable pump with sleeve and squeeze bulb.

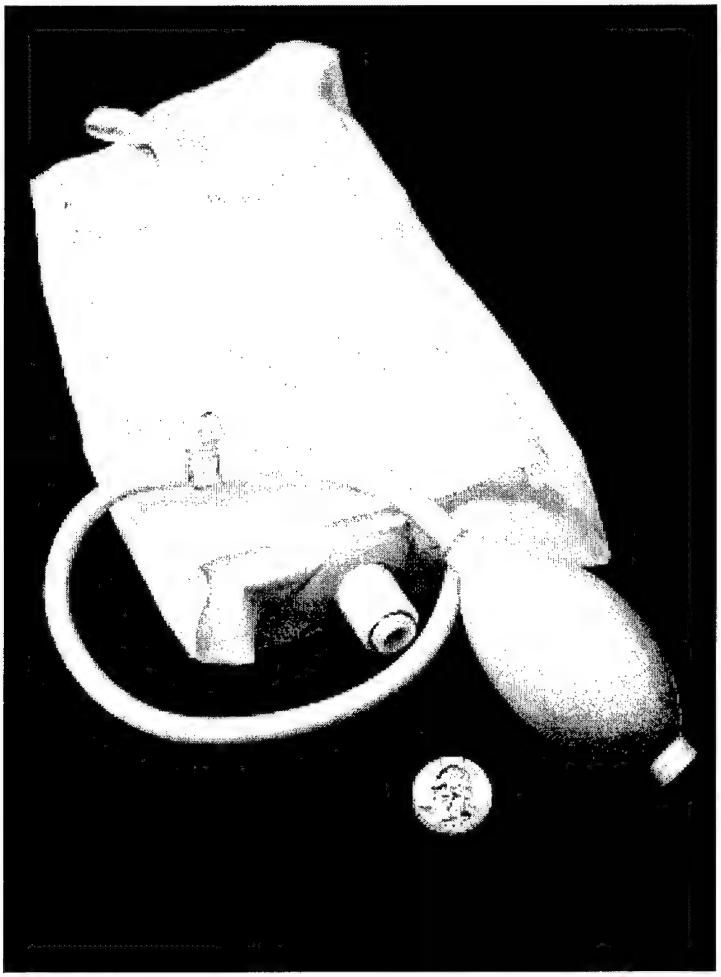


Figure 18: Infusable pressure bag system.

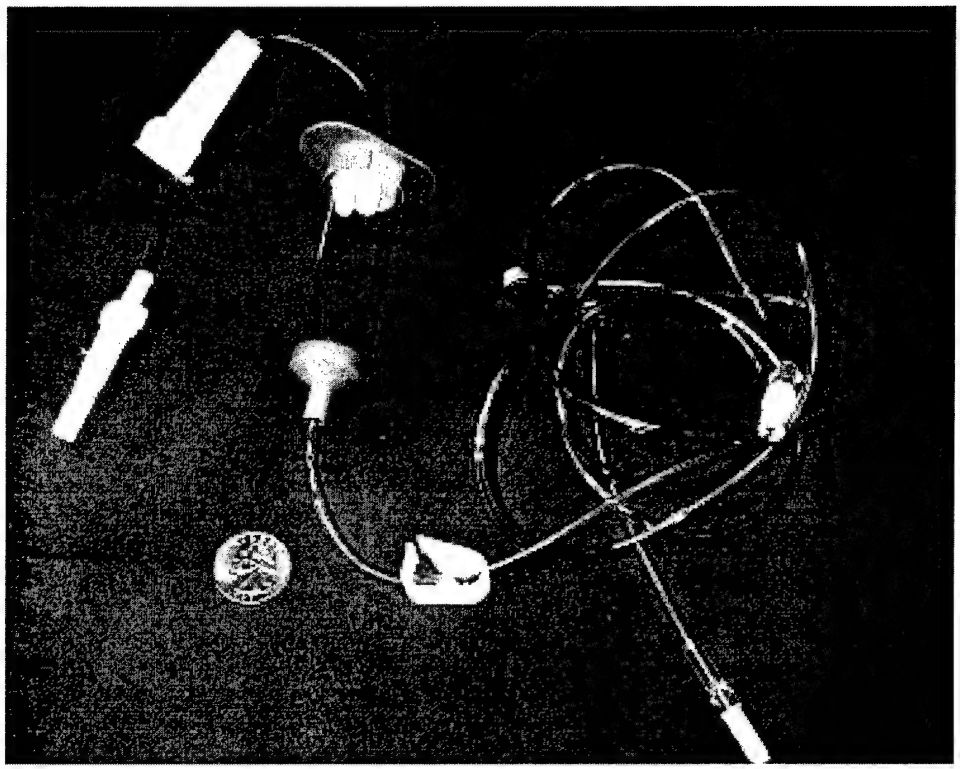


Figure 19: Select-3 IV tubing allows a choice of three different drip rates.

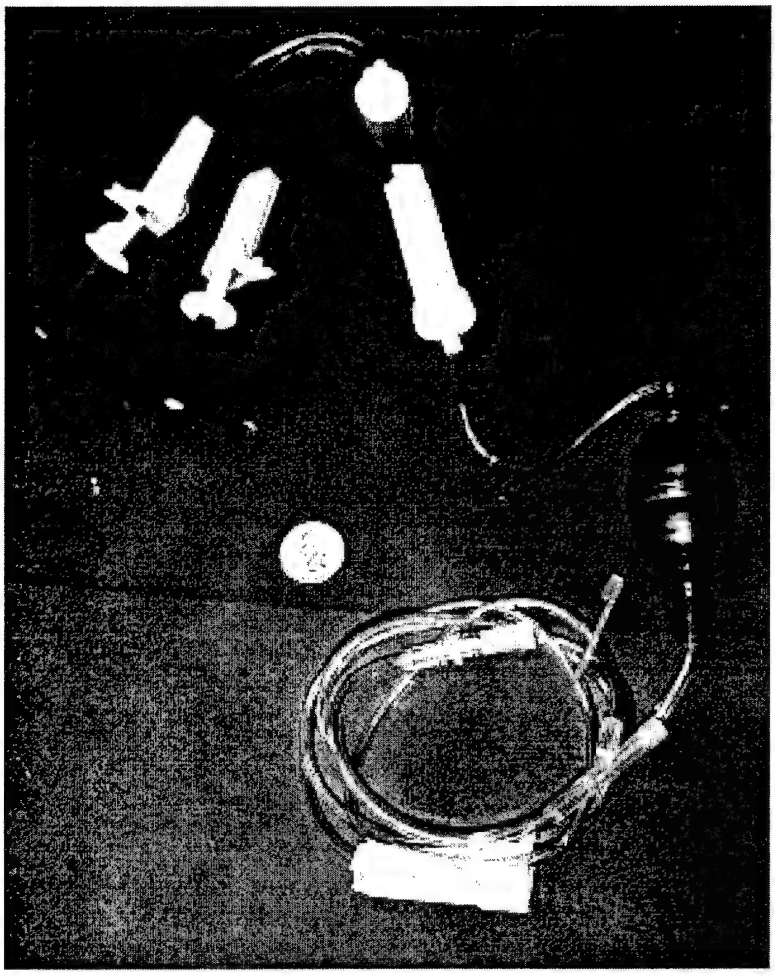


Figure 20: Y-Type Blood Set is IV tubing with an in-line squeeze bulb which allows for rapid volume administration of IV fluids.

Figure 21: Questionnaire One

Infusion Pumps:
Potential for the Special Operations Environment

Questionnaire One

Please circle YES or NO where appropriate. Write in available space and on the back of your questionnaire for open-ended questions. Thank you for your input.

Do you presently carry any infusion pump devices into the field? YES NO

If so, what kind of pump do you carry?

If so, have you ever used that pump? YES NO

Please give a brief, generic description of the scenario in which you used the infusion pump.

Please write in perceived advantages and/or disadvantages for each of the evaluated systems below.

Medi~SIS Syringe Infusion System
(blue and white plastic spring syringe system)

SpringFusor
(green and white syringe system)

BandIts
(rubber band syringe pumps)

Baxter Intermates
(baby bottle style balloons)

DIB (Drug Infusion Balloons)
(balloons in collapsible covering)

Microject
(tan plastic electric pump)

Infusion Dynamics
(black volume pump w/ credit card battery)

Liberty
(blue and white plastic box)

IV Push
(orange plastic box)

Israeli
(green spring)

Pressure Infuser
(green pump bag)

Infusable
(white pump bag)

Selec-3 IV tubing set
(selectable drop chamber)

Y-type Blood set with pump
(IV tubing with pump bulb)

Which of the evaluated infusion pumps, if any, would you carry into the field? Why?

Do you feel there is a need for infusion pumps? Why? YES NO
(i.e. volume infusion, medication administration)

Figure 22: Questionnaire Two

Infusion Pumps:
Evaluation for Potential Use in the
Special Operations Environment

Do you presently carry any infusion aids (i.e. pressure bag, pressure spring, pump, etc.)?

YES NO

If yes, then what items do you carry?

The infusion devices you are looking at may divided into small volume and large volume types. Small volume pumps could be used for infusion of drugs such as antibiotics. Large volume pumps could be used for resuscitative fluid administration. Large volume pumps may pump at specified or unspecified (exact rate unknown, often infuse at fastest rate possible) rates.

When evaluating the infusion pumps below keep in mind

A. potential applications, simplicity, ruggedness, ability to eliminate air, allowance for avoiding elevation of fluid bag
B. size, weight, collapsibility, need for batteries, durability, reusability
C. feasibility for Special Operations use

Rank the following infusion systems according to the following system

5 would carry this infusion pump on all missions
4 would carrying this infusion pump on specific missions
3 would have this infusion pump available on insertion/extraction platforms
2 would consider using this infusion pump with modifications
1 would never carry this infusion pump

(please comment on why you ranked the infusion pump in that manner, state potential modifications, advantages/disadvantages, feasibility of use far forward)

<u>Small volume</u>

Band-It (rubber band system)

10cc

20cc

Spring Fusor (green tubes into which syringe is inserted)

10cc

30cc

Medi-Sis 20 (white tube into which syringe is inserted, blue screw for pressure)

DIB (Drug Infusion Balloon elastomeric system, plastic ball)
202E (20cc vol, 20cc/2hr)

201E (20cc vol, 20cc/1hr)

20.5E (20cc vol, 20cc/0.5hr)

Large Volume

DIB (Drug Infusion Balloon elastomeric system, plastic ball and collapsible)
1001 V (100cc vol, 100cc/1hr)

2002 V (200cc vol, 200cc/2hr)

2001 V (200cc vol, 200cc/hr)

Intermate (elastomeric system, plastic ball)
IM SV 100 (vol 100, 100cc/hr)

IM SV 200 (vol 100, 200cc/hr)

IM LV 100 (vol 250, 100cc/hr)

IM LV 250 (vol 250, 250 cc/hr)

IM XLV 250 (vol 500, 250 cc/hr)

Microject 200 (small disposable electronic pump, 4 dials, 13 L driver life)

M100 (nondisposable electronic pump, 1 dial, card battery lasts >24 hr at highest infusion rates, eliminates air)

Israeli Spring (drab green, folding device)

IV Push (orange box)

Pressure Infuser (green, nylon inflatable bag)

Infusable (white, nylon disposable inflatable bag)

Figure 23: Compiled answers to Questionnaire One completed by 15 Navy Special Warfare corpsmen.
Blue text – represents answers

Infusion Pumps:
Evaluation for Potential Use in the Special Operations Environment

Questionnaire One

Please circle YES or NO where appropriate. Write in available space and on the back of your questionnaire for open-ended questions. Thank you for your input.

	YES	NO
Do you presently carry any infusion pump devices into the field?	(10)	(5)

If so, what kind of pump do you carry?

BP cuff system – 5
Infusable - 5

	YES	NO	None
If so, have you ever used that pump?	(5)	(8)	(2)

Please give a brief, generic description of the scenario in which you used the infusion pump.

Crush injury LLE and RUE following jump
Use often while transporting patients
Used during helicopter transport
Only in controlled ER environment
Rapid infusion for rehydration
Clinical setting only
When unable to hold bag up overhead

Please write in perceived advantages and/or disadvantages for each of the evaluated systems below.

Medi~SIS Syringe Infusion System
(blue and white plastic spring syringe system)

too heavy	would be hands-off
not durable enough	
no field use	
too large	
may rust	
can't see need	

SpringFusor
(green and white syringe system)

no field use	
too large	
can't see need	

BandIts
(rubber band syringe pumps)

no field use	good size and weight
rubber bands break	
no application	
too much of hassle	
would rather do it manually	

Baxter Intermates
(baby bottle style balloons)

too breakable	known infusion rate
no field use	
can't think of a reason to use it	
bulky	

DIB (Drug Infusion Balloons)
(balloons in collapsible covering)

no field use
can't think of a reason to use it
too much space taken up

can be useful on extraction
possible use long periods in field
known infusion rate
good size
compact

Microject
(tan plastic electric pump)

no electric
breakable
no field use
forget electric anything
too many moving parts
expensive
batteries need to be accessible
don't want to depend on batteries

Infusion Dynamics
(black volume pump w/ credit card battery)

maybe waterproof it
no field use
water will destroy it
too expensive
potentially too delicate

excellent for extraction
may be useful for extraction
field trials if made waterproof
allows IV bag to lay flat

Liberty
(blue and white plastic box)

slightly oversized
breakable
no field use
too big

useless

IV Push

(orange plastic box)

no field use
way too big
bulky
not sturdy
junk
pump bags work just as well

Israeli

(green spring)

heavy
non-pliable (difficult to pack)
no field use
large, bulky, cumbersome

durable
no need to depend on squeeze bulb
easy

Pressure Infuser

(green pump bag)

?rugged
compared to Infusable costs too much
same as Infusable

good
compact
good basic option
conserves space

Infusable

(white pump bag)

good
best to use in field
most reasonable
compact
light, small, cheap, effective
cost effective
easy to use

have had no trouble w/ it in field,
it works well
durable
simple
good basic option
conserves space

Selec-3 IV tubing set
(selectable drop chamber)

no
has place in hospital
might be used, most likely not appropriate
I don't need a selection

adjustable rate is great
no need to set up extra equipment

Y-type Blood set with pump
(IV tubing with pump bulb)

has place in hospital

good
appropriate
simple
lightweight
inexpensive
cost effective
does not require carrying additional item
good for blood

Which of the evaluated infusion pumps, if any, would you carry into the field? Why?

Pressure Infuser (3)
Infusable (11)
Lightweight, easy, most appropriate
Best for field
Works well, doesn't take up much space
How about a different color?
Less moving parts the better

Y-blood set (6)

Do not have to carry anything extra (replaces other IV tubing), the last thing wanted is to carry more gear

Infusion Dynamics (4)

Lets your hands be free, self monitored

Not necessary for field, but could use for extractions

Israeli (2)

Select-3 (2)

Do you feel there is a need for infusion pumps? Why? (i.e. volume infusion, medication administration)	YES (9)	NO (6)

frees your hands up to carry on mission, take care of more people or even get back to extraction
there are times when forced fluids are necessary but you have other things to be concerned with, a pump takes up your slack
infusion of IV fluid at high volume
primarily for volume infusion
long Casevac delay
hands free to provide other medical treatment or tactical tasks
at least pressure bag system needed
so you don't have to hold the bag up

someone usually able to perform function by hand
never used pump in field, put direct pressure on the bag
just have someone squeeze the bag
use BP cuff
there is no need to carry more equipment if it does not greatly improve quality of care (none of the items do that in my opinion)

Figure 24: Compiled answers from 11 Special Operations personnel answering Questionnaire Two..
Red text represents respondents' answers
Blue test represents investigator comments

Infusion Pumps:
Evaluation for Potential Use in the
Special Operations Environment

Questionnaire Two

Do you presently carry any infusion aids (i.e. pressure bag, pressure spring, pump, etc.)?

YES 7 NO 4

If yes, then what items do you carry?

Usually pressure spring
No, but at times, I have used the Israeli Spring and a BP cuff.
White pressure infuser
White pneumatic large pressure volume pump
Pressure bag
Sometimes carry a BP cuff and wrap it around a IV bag.
Infuser bag.

The infusion devices you are looking at may divided into small volume and large volume types. Small volume pumps could be used for infusion of drugs such as antibiotics. Large volume pumps could be used for resuscitative fluid administration. Large volume pumps may pump at specified or unspecified (exact rate unknown, often infuse at fastest rate possible) rates.

When evaluating the infusion pumps below keep in mind

A. potential applications, simplicity, ruggedness, ability to eliminate air, allowance for avoiding elevation of fluid bag
B. size, weight, collapsibility, need for batteries, durability, reusability
C. feasibility for Special Operations use

Rank the following infusion systems according to the following system

5 would carry this infusion pump on all missions
4 would carrying this infusion pump on specific missions
3 would have this infusion pump available on insertion/extraction platforms
2 would consider using this infusion pump with modifications
1 would never carry this infusion pump

(please comment on why you ranked the infusion pump in that manner, state potential modifications, advantages/disadvantages, feasibility of use far forward)

Small volume

Band-It (rubber band system)

10cc and 20cc options

I would push it slowly on my own.

This small amount of volume I can handle on my own w/o worrying about another piece to break.

I trust my own ability to slow/fast push IV drugs w/o adding more gear to my already full kit.

100% (11/11) of respondents answered choice 1 indicating that they would never carry this pump.

Spring Fusor (green tubes into which syringe is inserted)

10cc and 30cc options

Easier to do IV push on my own

This small amount of volume I can handle on my own w/o worrying about another piece to break.

I trust my own ability to slow/fast push IV drugs w/o adding more gear to my already full kit.

Would possibly use to carry antibiotics

90% (9 of 10 people providing a response) answered choice 1, the remaining response marked choice 2.

Medi-Sis 20 (white tube into which syringe is inserted, blue screw for pressure)

Easier to do IV push on my own but might be useful to store antibiotics.

This small amount of volume I can handle on my own w/o worrying about another piece to break.

I trust my own ability to slow/fast push IV drugs w/o adding more gear to my already full kit. Also it is large, heavy, fragile and not very durable.

90% (9 of 10 people providing a response) answered choice 1, the remaining response marked choice 2.

DIB (Drug Infusion Balloon elastomeric system, plastic ball)

202E (20cc vol, 20cc/2hr)

201E (20cc vol, 20cc/1hr)

20.5E (20cc vol, 20cc/0.5hr)

Good idea but plastic will break

Seems like a good idea but not sure about durability. Time with the Team's test [unsure of meaning of last statement]

Although it appears to be relatively durable and lightweight, I don't administer drugs requiring a specific, finite rate very often.

80% (8/10) answered choice 1, while one evaluator chose 2 and the other 3.

Large Volume

DIB (Drug Infusion Balloon elastomeric system, plastic ball and collapsible)

1001 V (100cc vol, 100cc/1hr)
2002 V (200cc vol, 200cc/2hr)

Fluid volume too minimal for field use.

77.8% (7 of 9 people) answered choice 1 and the remaining evaluators chose 2.

2001 V (200cc vol, 200cc/hr)

Durable and lightweight but I don't see much field application.

66.7% (6 of 9) made choice 1, 3 people made choice 2.

Intermate (elastomeric system, plastic ball)

IM SV 100 (vol 100, 100cc/hr)
IM SV 200 (vol 100, 200cc/hr)
IM LV 100 (vol 250, 100cc/hr)
IM LV 250 (vol 250, 250 cc/hr)
IM XLV 250 (vol 500, 250 cc/hr)

Only problem is that plastic will break
Hard plastic doesn't typically fair well in a field environment, esp. in cold weather environment. It's lightweight but very bulky.

77.8% (7 of 9 people responding) answered choice 1, with the remaining picking choice 2.

Microject 200 (small disposable electronic pump, 4 dials, 13 L driver life)
Gives fast amounts of volume but electronics [are] useless if wet.
If it's electrical, it's not reliable.
Requires batteries; it is fragile, and appears to be too frail.

6 of 9 responders made choice 1, whereas 1 made choice 2 and two made choice 3.

M100 (nondisposable electronic pump, 1 dial, card battery lasts >24 hr at highest infusion rates, eliminates air)
If it's electrical, it's not reliable.
Would be great for a MEDEVAC aircraft. Too costly for individual issue.

Six evaluators made choices of either 3 or 4. Four of 9 respondents said they would place this on an insertion/extraction platform, and 2 said that they would carry it for some missions. The remaining 3 who responded said they would not carry the device.

Israeli Spring (drab green, folding device)
Seems useful, but takes up a lot of space though. Easier to carry collapsible bag listed below.[pressure infusor or infusable]
A little bulky, but works very well.
Simple, durable, compact. Could be lighter.

Answers choices were evenly distributed among answer choices 1-5, with no obvious agreement.

IV Push (orange box)
Big and useless
Too big, too unreliable, too bulky, and not rustproof.

100% (n=10) answered choice 1.

Pressure Infuser (green, nylon inflatable bag)
Would field test to determine sturdiness.
Cost
A more expensive alternative to what I carry now, but appears durable.

44.4% (4/9) indicated they would use it for insertion/extraction platforms, while two of nine would carry it on some missions. One of the evaluators would carry it for all missions. Although the other two made choices 1 and 2.

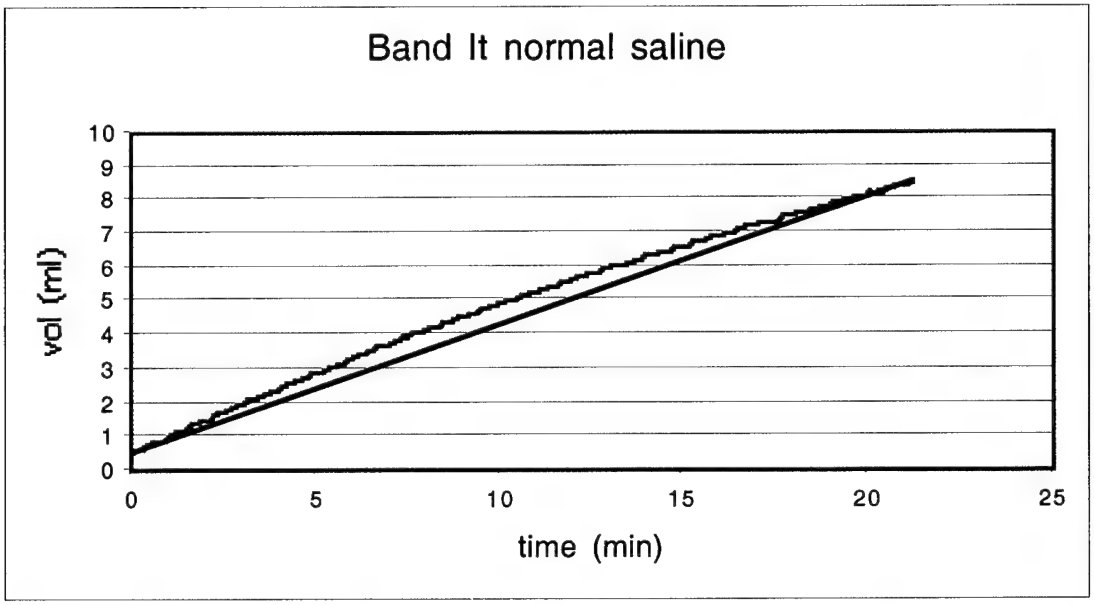
Infusable (white, nylon disposable inflatable bag)
Would field test to determine sturdiness.
This is what I carry now. It's inexpensive, light and compact. Could be more durable.

Eight of the ten (80%) people who gave an answer would either carry this on all missions (4) or some missions (4). One person stated that they would use it for insertion/extraction. One person said they desired modifications. No evaluator gave this device choice 1.

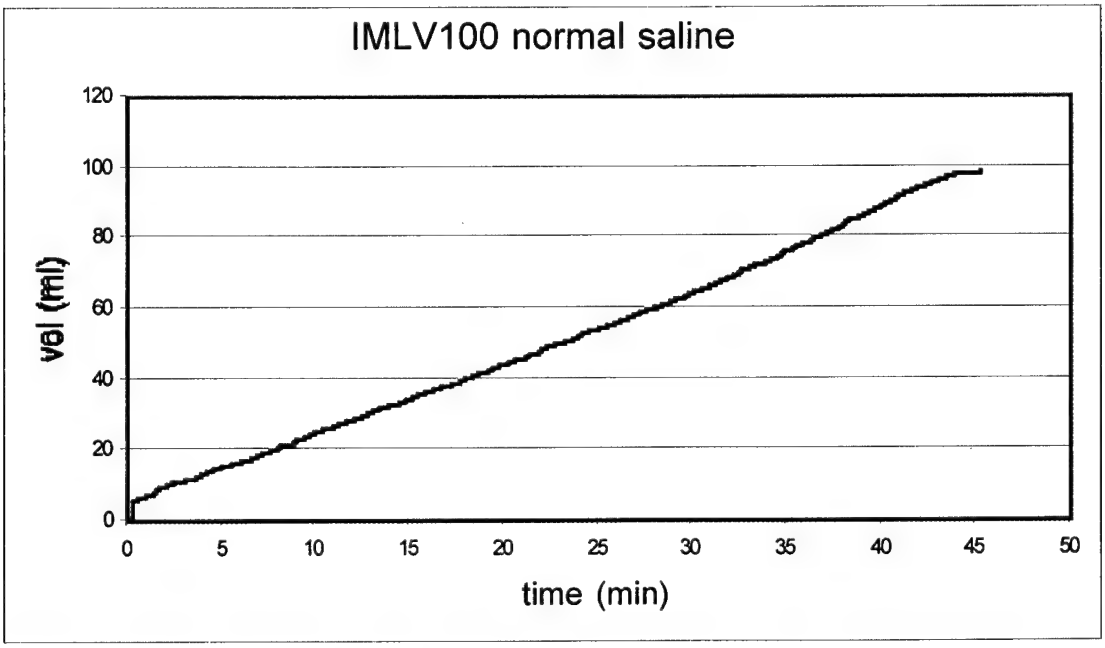
Blood Set

[I] like the concept; would be great for a second line.
However [would] need to modify the tubing. Only need one bag and no need for 2nd hook-up.
Use with modification (other attachment taken out to have a regular IV tubing with bulb.
Limits gear to be carried, light and compact, would require additional training.

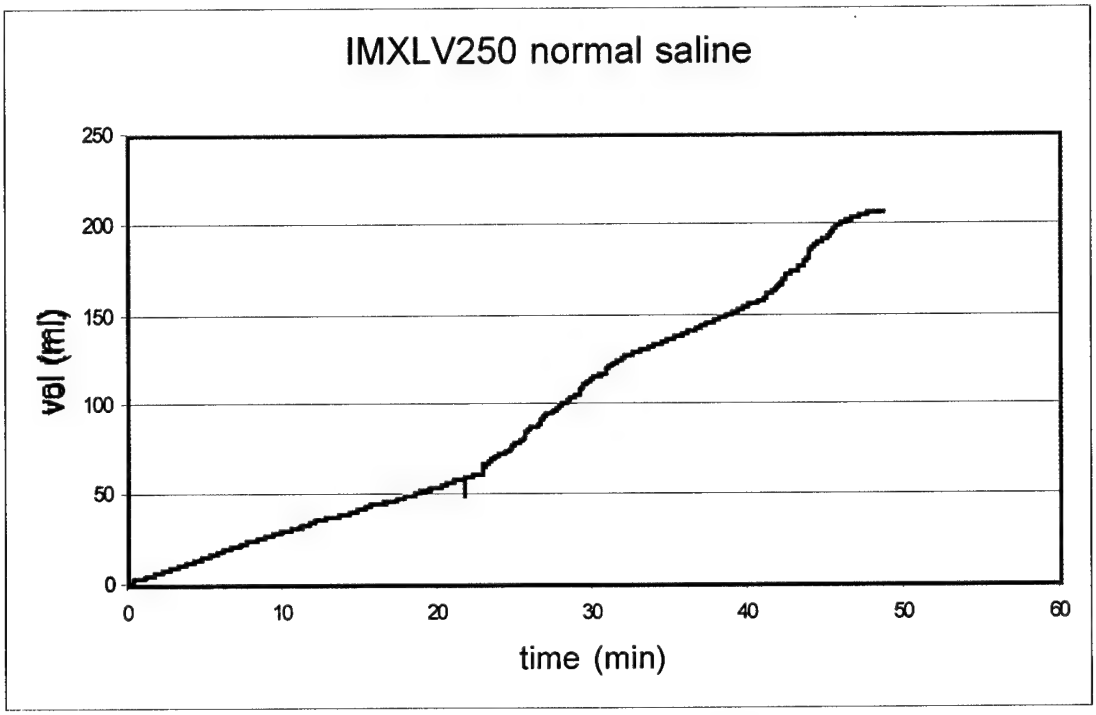
Although this questionnaire did not have the Y-Blood Set listed on the questionnaire, eight people wrote in their answers. Six of those 8 (75%) said they would carry it on all missions (4) or some missions (2). The remaining two made choices 3 and 2. Like the Infusable, no evaluator gave this device choice 1.



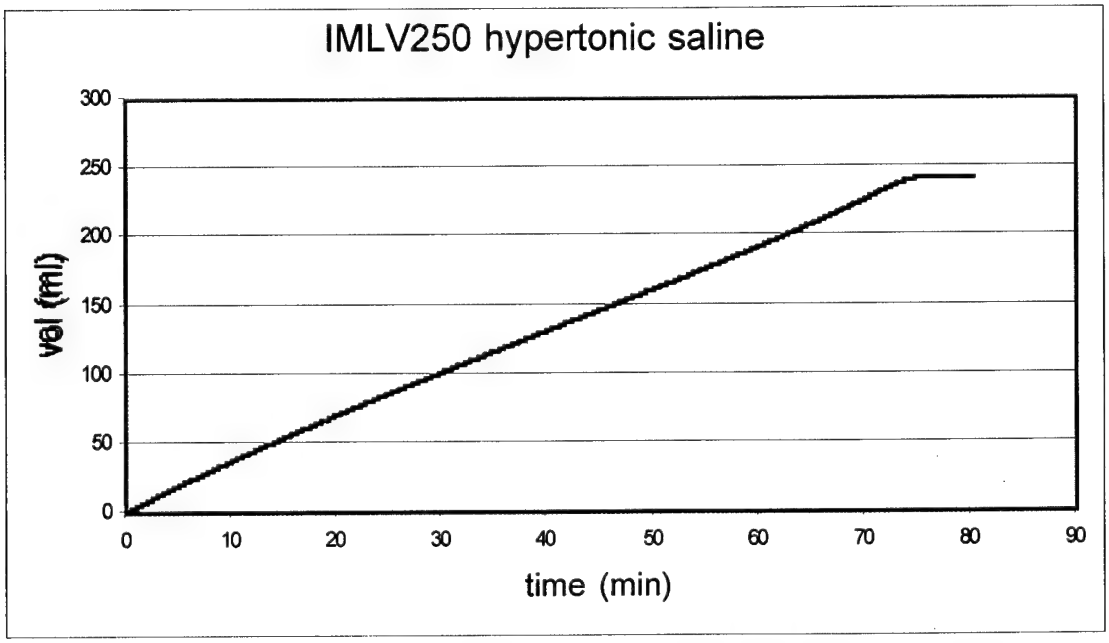
Graph 1: Band It infusion rate seen in the upper curved line shows adequate infusion rate for antibiotic administration.



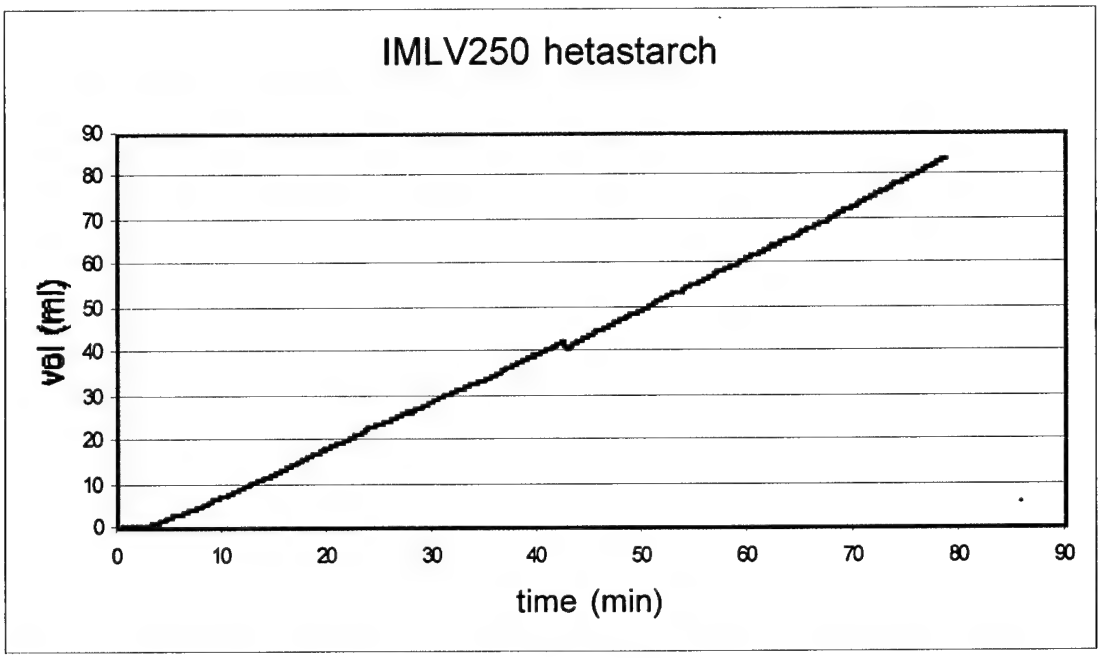
Graph 2: Baxter Intermate Large Volume (250cc reservoir) 100 cc/hr elastomeric balloon delivered 100cc of normal saline in approximately 45 minutes.



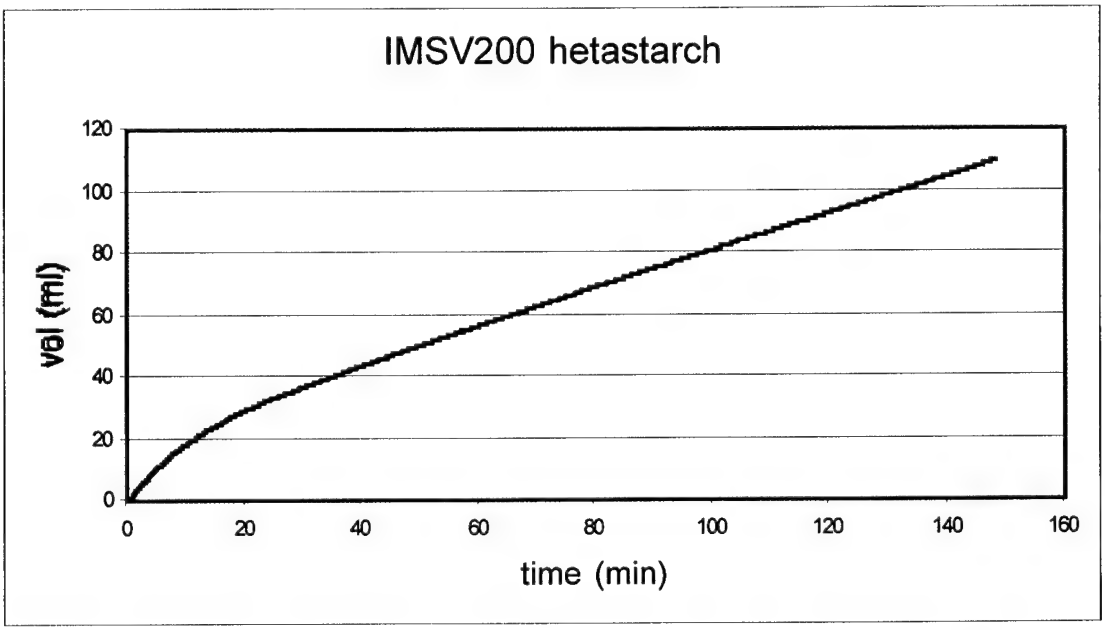
Graph 3: The Baxter Intermate XLV (500cc reservoir) 250 cc/hr elastomeric balloon delivered approximately 210 cc of normal saline in 50 minutes.



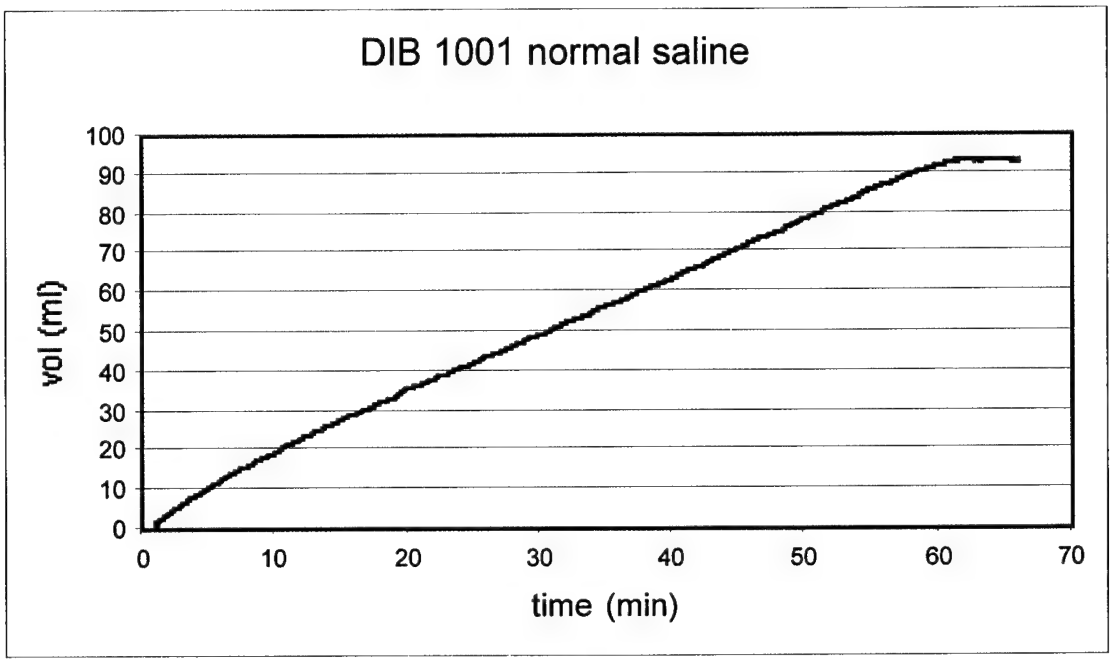
Graph 4: The Baxter Intermate LV (250cc reservoir) 250 cc/hr elastomeric balloon delivered approximately 240 cc of hypertonic saline (7.5% saline) in 74 minutes.



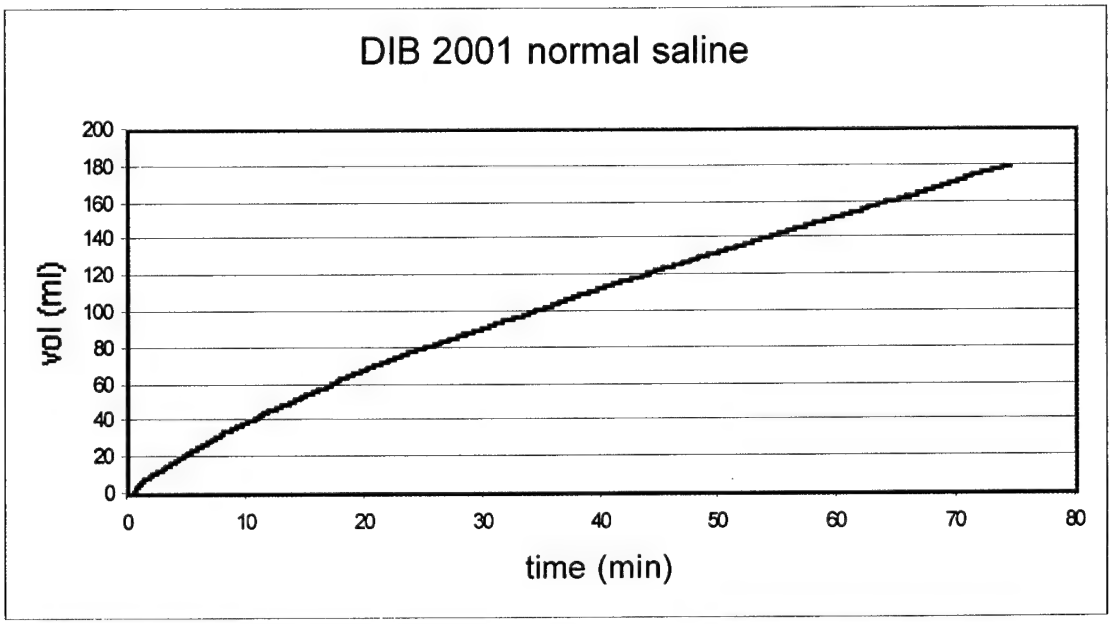
Graph 5: The Baxter Intermate LV (250cc reservoir) 250 cc/hr elastomeric balloon delivered a much slower rate (approximately 80cc in 77 minutes), when infusing hetastarch (Hespan).



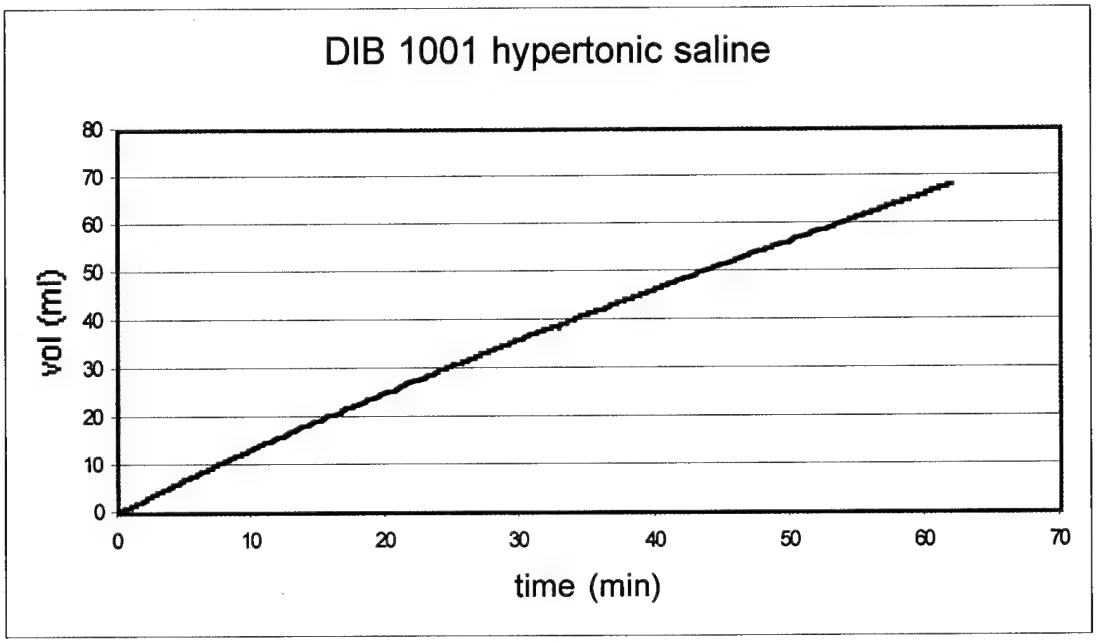
Graph 6: The Baxter Intermate SV (100cc reservoir) 200 cc/hr elastomeric balloon delivered a much slower rate (approximately 100cc in 130 minutes) when infusing hetastarch (Hespan).



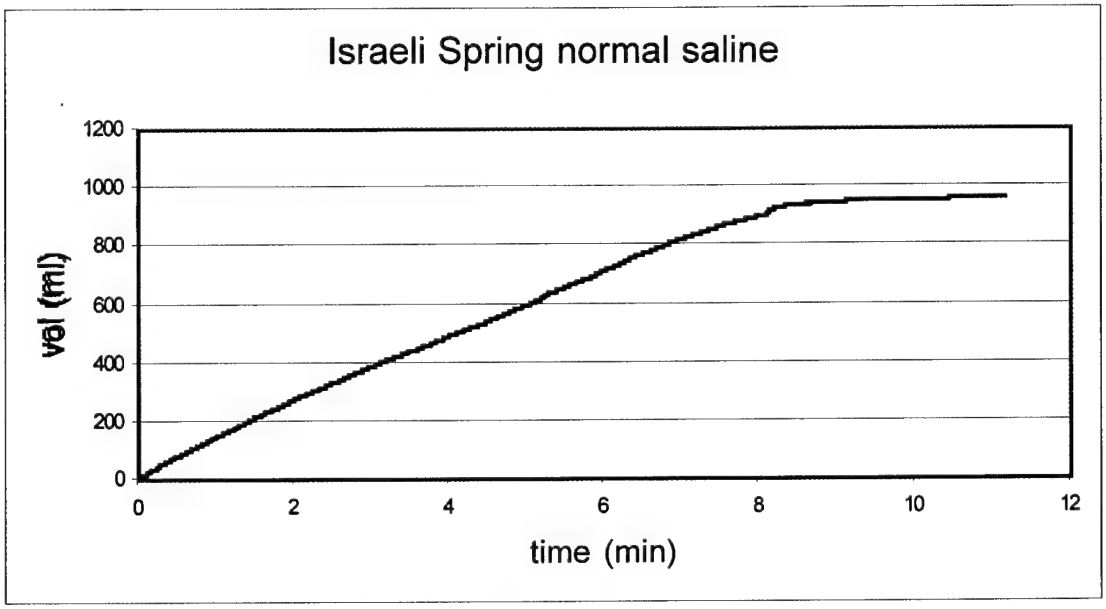
Graph 7: The Drug Infusion Balloon (DIB) 1001 (100 cc/hr) delivered approximately the reported infusion rate of slightly over 90 cc of normal saline at 60 minutes.



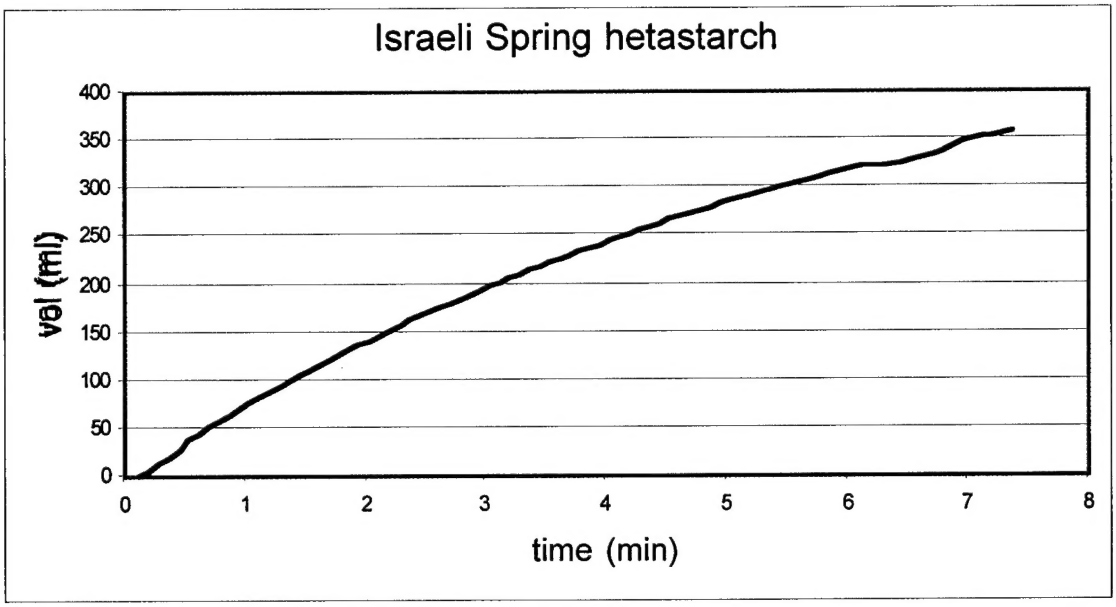
Graph 8: The Drug Infusion Balloon (DIB) collapsible 2001 model delivered 180cc of normal saline in just over 70 minutes, close to its reported 200 cc per hour rate.



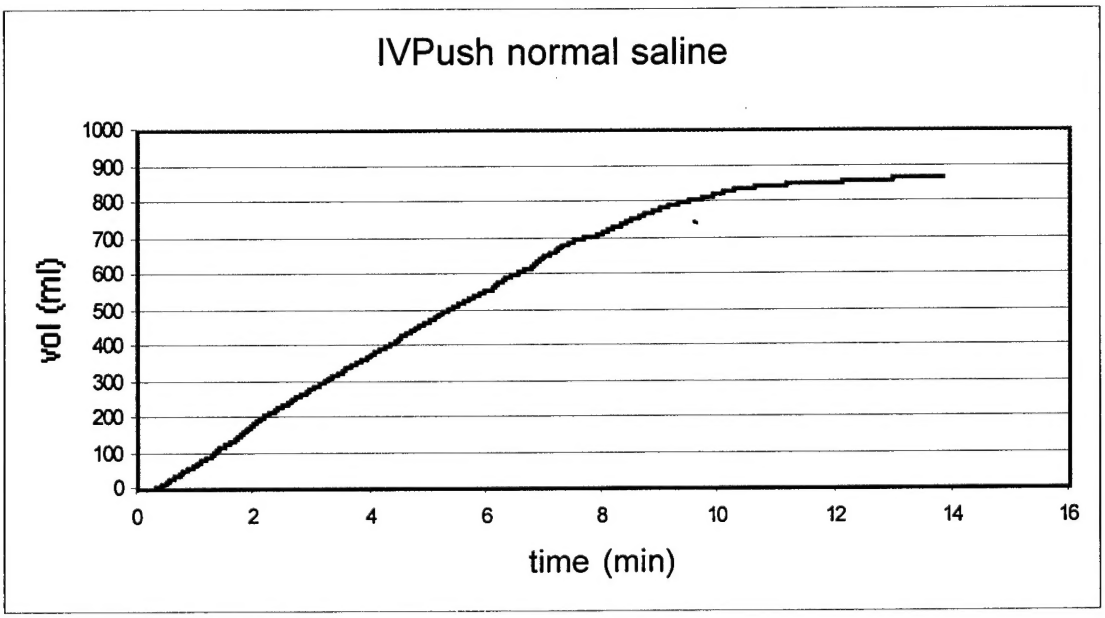
Graph 9: The Drug Infusion Balloon (DIB) collapsible 1001 model delivered approximately 68cc of hypertonic saline (7.5% saline) in 60 minutes.



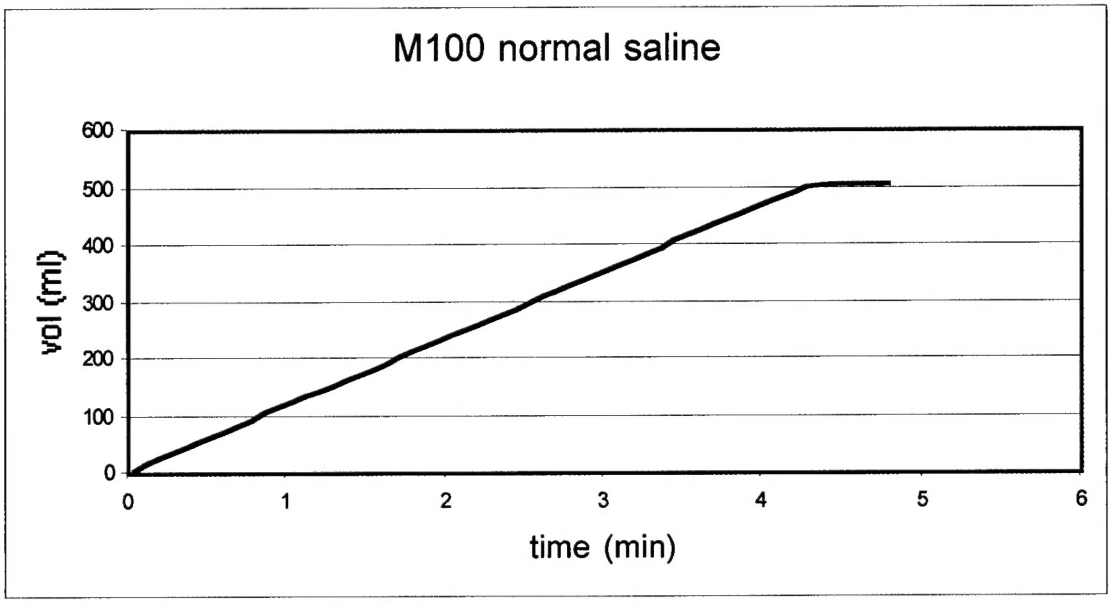
Graph 10: The Israeli Spring was able to infuse approximately a liter of normal saline in under 9 minutes.



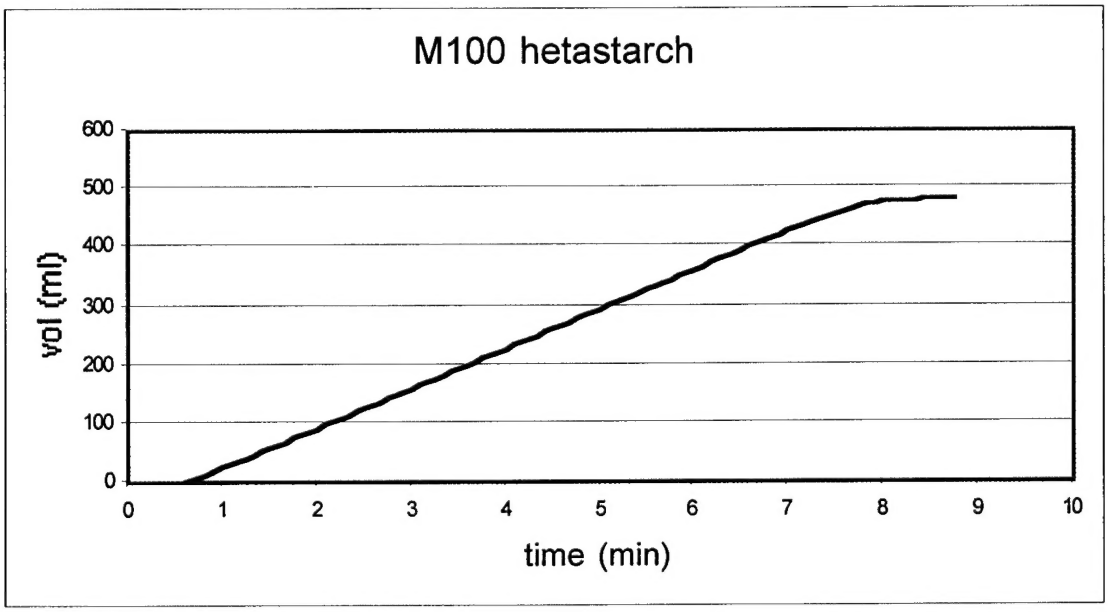
Graph 11: The Israeli Spring pumped 250cc of hetastarch (Hespan) in just over 4 minutes.



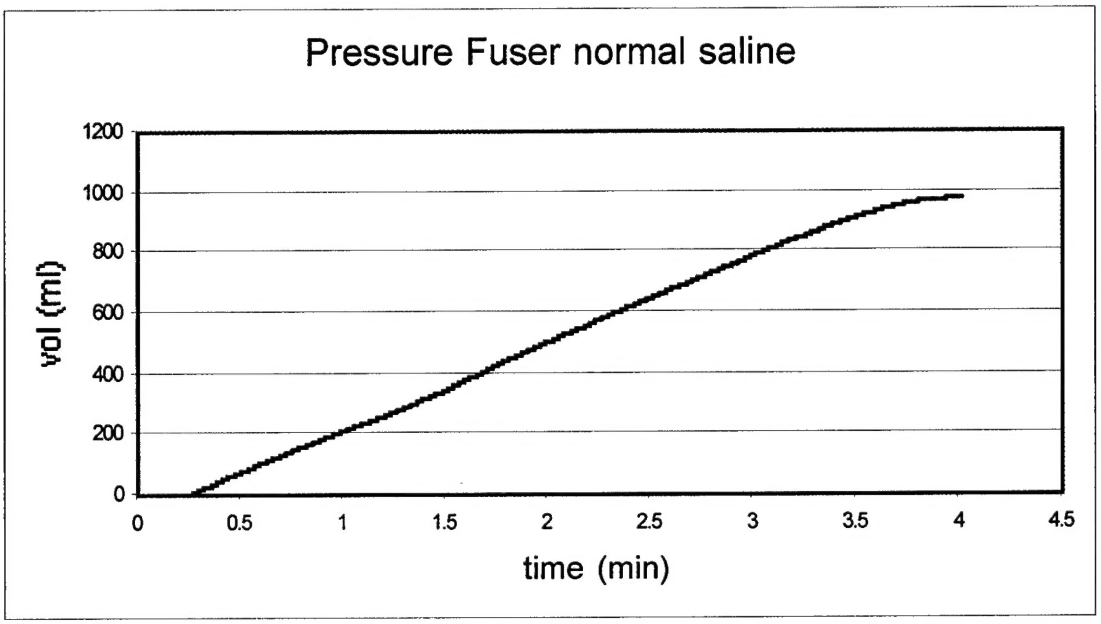
Graph 12: IVPush infusion tapered and plateaued at approximately 850cc of normal saline after 11 minutes.



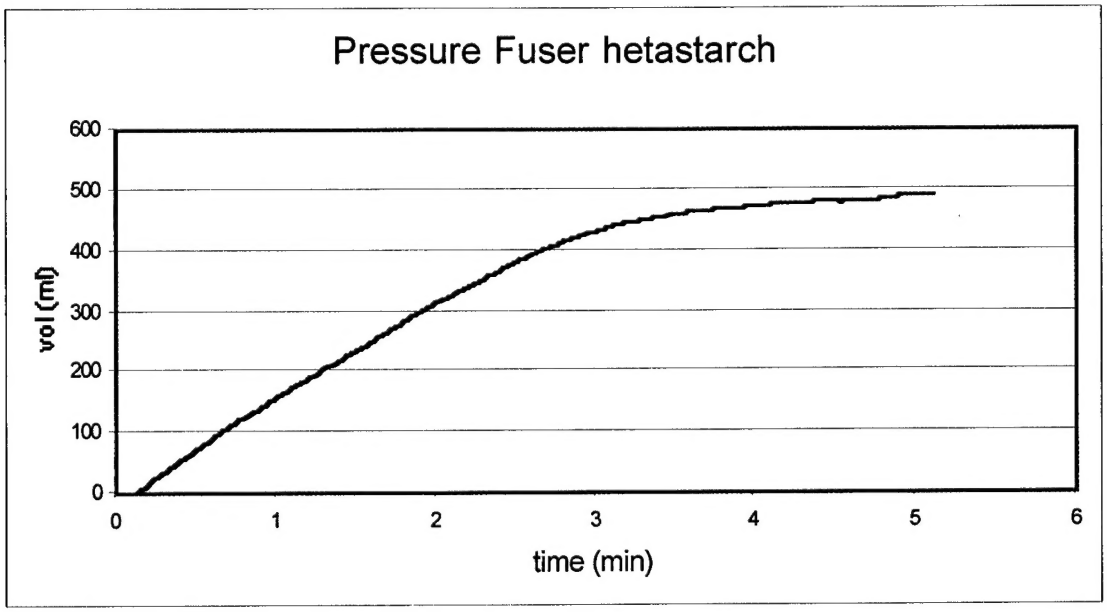
Graph 13: Infusion Dynamics' M100 Power Infuser demonstrates its rapid infusion by pumping 500 cc of normal saline in just over 4 minutes.



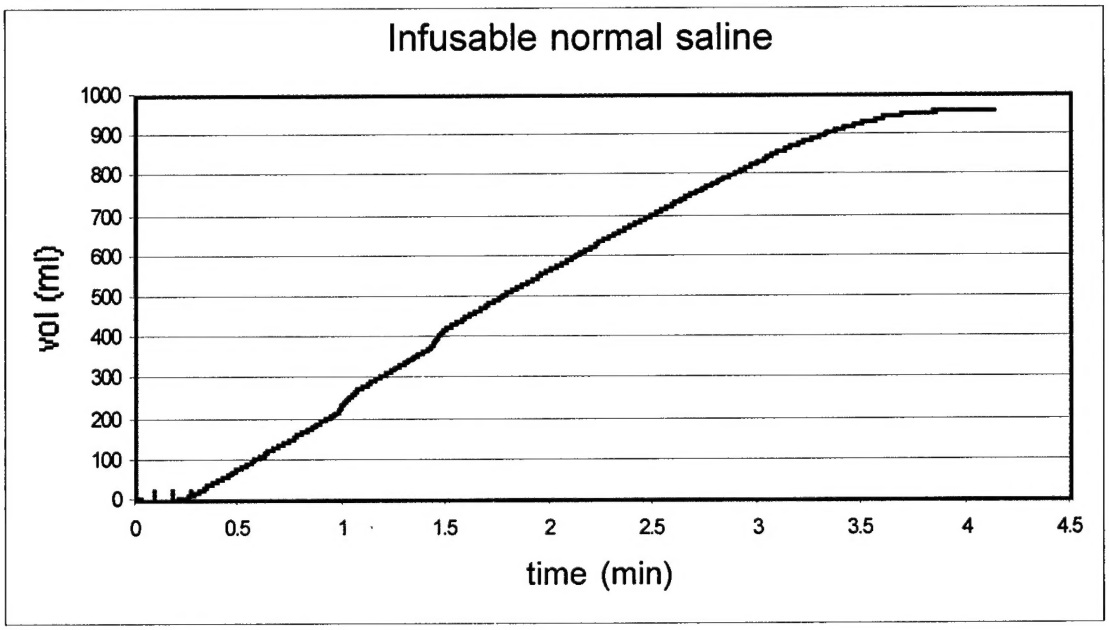
Graph 14: M100 demonstrates rapid infusion of hetastarch (Hespan).



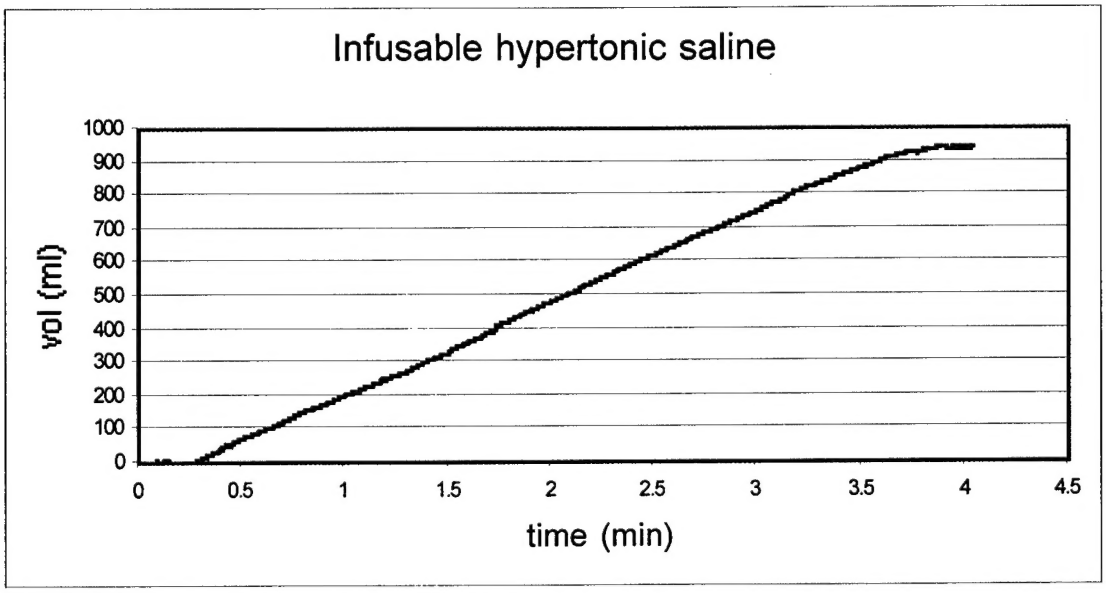
Graph 15: Pressure Fuser infuses 1000 cc of normal saline in approximately 4 minutes.



Graph 16: Pressure Fuser empties a 500 cc bag of hetastarch in approximately 4 minutes.



Graph 17: Infusable delivers 960 cc in 4 minutes.



Graph 18: Infusable administers 940 cc in 4 minutes.